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"THE ENGINEER," AUGUST 25, 1939

Printed on thin paper for overseas circulation.

With METALLURGICAL SUPPLEMENT

The Engineer

VOL. CLXVIII.—No. 4363 28, ESSEX ST., STRAND, LONDON, W.C. 2 AUGUST 25, 1939

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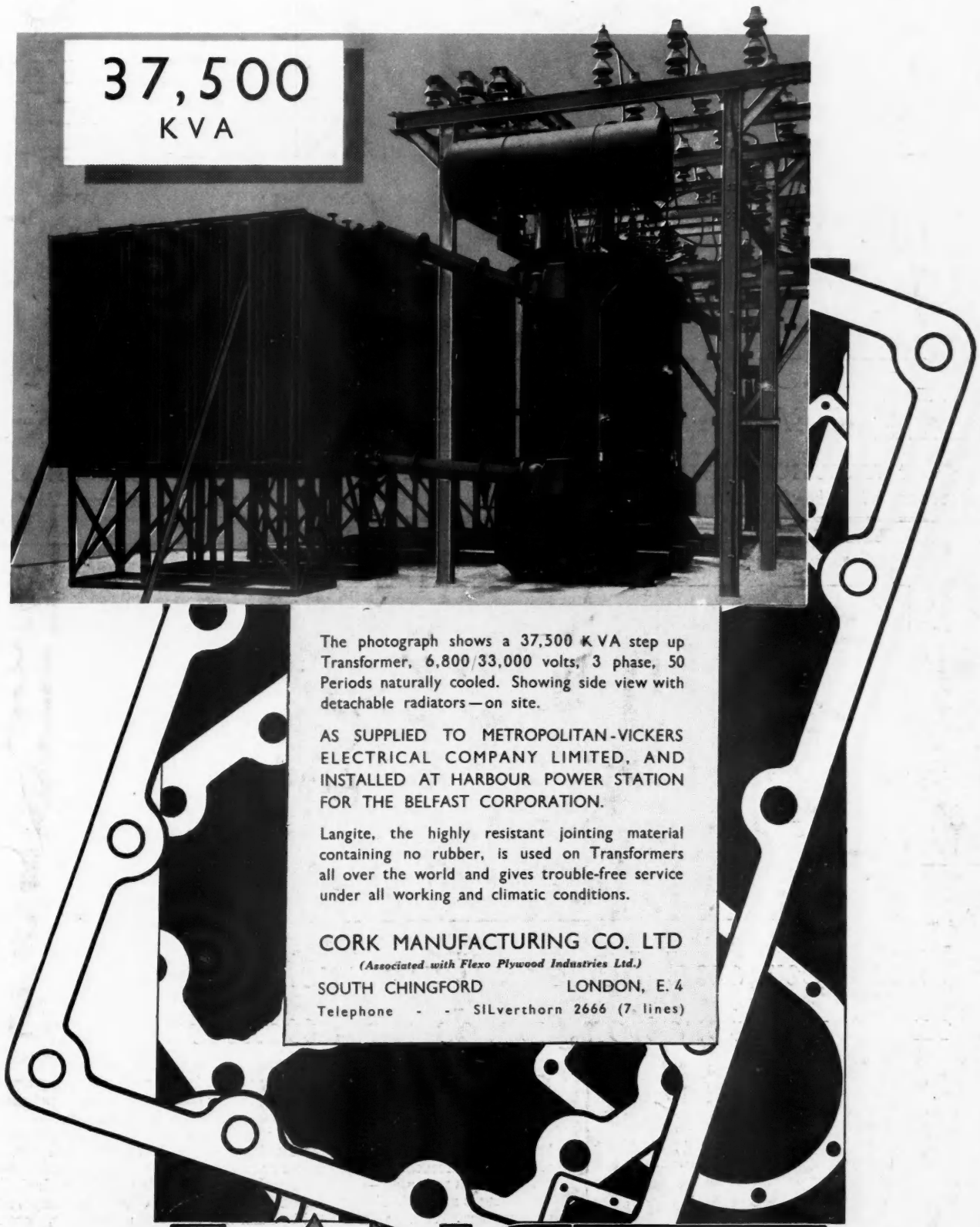

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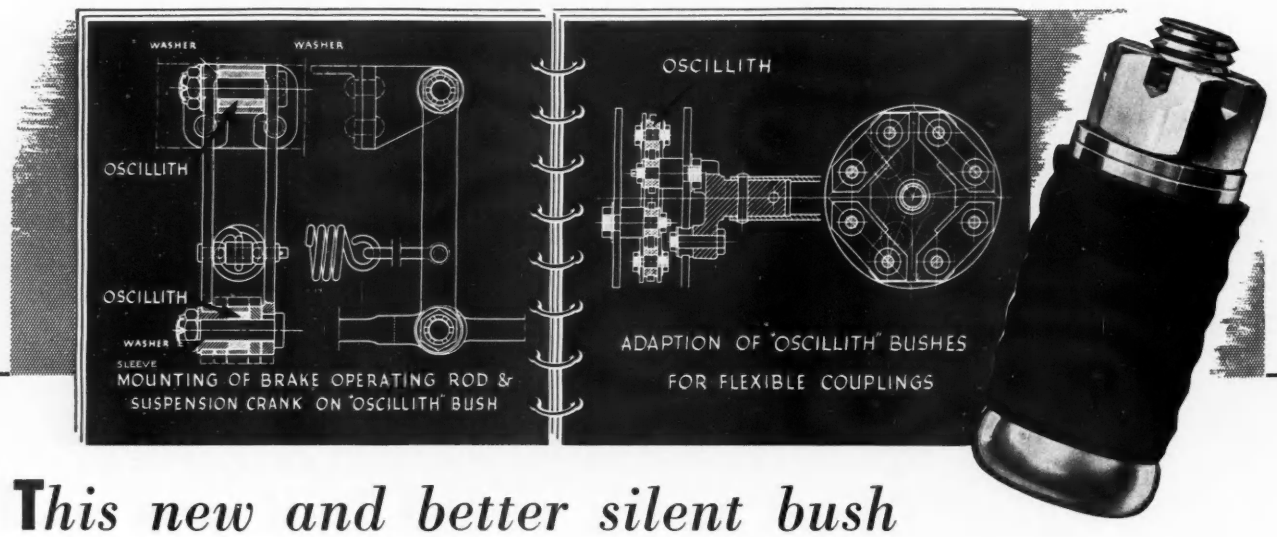

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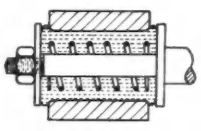
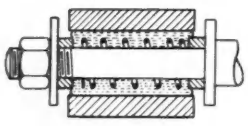


With the assembly most generally employed, a nut deforms the bush between the washers until a non-slip contact is established between spindle and housing.



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A New Water Speed Record

On Saturday, August 19th, Sir Malcolm Campbell, in his speed boat "Bluebird II," set up a new water speed record of 141·74 m.p.h. on Coniston Water. The speed on the southward run was 142·85 m.p.h. and that on the northward run 140·62 m.p.h. After the record run, which was officially observed by the Marine Motoring Association, Sir Malcolm paid a tribute to the design and workmanship of the hull and engines. He said that although the boat was powered with the twelve-year-old practice engine, a Rolls-Royce unit of 1760 H.P., a lot had been learned with regard to the efficiency of the hull construction. Modifications to the design could now be made which would give a lot more speed in hand, especially with the larger engine of 2150 H.P., which had still to be tried. The reason for the slower speed on the return journey was, Sir Malcolm stated, because he had only a mile in which to work up the speed before entering on the measured mile. But for the fact that the boat was carrying 160 lb. of ballast in the shape of 55,000 ping-pong balls to give extra buoyancy, he felt sure that even with the smaller engine a speed of about 150 m.p.h. might have been reached. Commander Peter du Cane, of Vosper, Ltd., who designed the hull of "Bluebird II," praised the skill and courage of Sir Malcolm and his handling of the boat, which on Friday, the second occasion of running, he did not hesitate to run at high speed. He said that valuable lessons had been learned, which would result in improved performance and greater safety in high-speed motor boats. They would, he said, be of the greatest value in the designing of the hulls of flying boats. Since 1930, when Sir Henry Seagrave was killed after setting up a new speed record on the waters of Lake Windermere of 98·76 m.p.h., speed records won by Commodore Gar Wood and Kay Don raised in 1932 the record to 124·91 m.p.h. During the last three years Sir Malcolm Campbell has won three successive records with speeds of 129·50, 130·91, and 141·74 m.p.h. respectively.

The Factory Inspector's Report

The annual report of Sir Duncan R. Wilson, H.M. Chief Inspector of Factories, which was published by the Stationery Office on Friday, August 18th, records a welcome decrease in the number of accidents in industry during the year under review, compared with the accident returns for the two previous years. In 1938 the total number of reported accidents in all places under the Factories Act was 180,103, of which 944 were fatal accidents. The decrease compared with the previous year was 6 per cent. for the total figure and 7 per cent. for the fatal accidents. In the manufacturing industries these decreases extended to 10 per cent. and 12½ per cent. respectively. In the case of some industries and some classes of machines, the report states, the decrease in accidents was still more pronounced, and in metal rolling mills, mainly in the iron and steel industry, the number of accidents fell by no less than 30 per cent. Accidents occurring on power presses fell by 25 per cent., while those which occurred in connection with transmission machinery fell by 17 per cent. It is true, it is pointed out, that this general decrease was to some extent due to the fewer numbers in employment, but the fact that the decrease is especially marked among fatal accidents occurring on factory premises encourages the hope that the safety requirements of the new Factory Act, which are particularly aimed at the prevention of the severe type of injury, have already begun to take effect. This view is further supported by the fact that the diminution in the number of accidents caused by overrunning or by crushing by overhead cranes, and those occurring on hoists and lifts, two causes for which special provision has been made for the first time, amounted to as much as 30 per cent. and 20 per cent. respectively. It is clear, however, Sir Duncan says, that there is still room for a bigger reduction of accidents in industry generally, and this result should be quickly attained by the exercise of greater care and more thought on the part of those concerned. In building operations there were increases of up to 20 per cent., which may be due in part to the wider scope of the Act. There was a large increase in falls through roofs covered with asbestos sheets. The number of accidents—99, with 17 fatalities—was the highest ever reached, but the new British Standards Institution specifications for this material should tend to prevent such accidents.

Science and Labour

A report of the Trades Union Congress General Council, which has recently been issued, states that the Scientific Advisory Committee, which was formed some time ago by members nominated by the British Association and the Trades Union Congress, and which held its first meeting on July 20th, has now laid down its programme. It is considered that subjects upon which the Committee might be consulted with a view to their effects upon labour and social conditions might include the following:—The present position of research in relation to industrial and occupational diseases, with a view to prevention rather than cure; researches into industrial fatigue and nerve strain, including systems of labour measurement, in relation to shorter working hours, holidays, and minimum periods for rest and recreation; nutritional needs and scientific criteria, in respect of different foodstuffs and their relation to public health, agricultural policy, and the standard of living; distribution and redistribution of the industrial population; the effects of new industries, new materials, new uses, and new processes upon the distribution, displacement, and character of labour; new uses for coal and other minerals; organisation, use, and distribution of power, and the prevention of smoke, dust, and noise. It was agreed that in view of the diversity of the subjects named above and of the special branches of knowledge represented on the Committee, the best method of working would be for definite investigations to be carried out by sub-committees or panels formed from the members of the Advisory Committee, the whole Committee meeting at intervals in order to receive reports and to advise on general questions. Three sub-committees were formed to deal with the two subjects first named and with new industries, with special reference to plastics, textile and non-textile industries, and with nutritional needs. The main functions of the Advisory Committee were also laid down and agreed upon.

H.M.S. "Erebus" Reconditioned

The monitor H.M.S. "Erebus," built during the war, which for some years has been in service as a cadets' training ship, has been reconditioned by John I. Thornycroft and Co., Ltd., at Woolston, Southampton, and has now been handed over to the Admiralty. It is expected that the ship will shortly sail for Cape Town, where she will serve as a guardship. It may be recalled that H.M.S. "Erebus" was laid down under the Emergency War Programme, and completed in 1916 by Harland and Wolff, Ltd., at Govan. She has twin-screw triple-expansion engines, taking steam from Babcock and Wilcox oil-fired boilers, and her designed horse-power is 6000, with a speed of about 12 knots. Her dimensions are:—Length 405ft. overall; breadth, 88ft.; and displacement 7200 tons. The work of reconditioning the ship, which normally would have been carried out at a Royal Dockyard, was entrusted to John I. Thornycroft and Co., Ltd., which firm also carried out the conversion of the White Star liner "Majestic" to the naval training ship "Caledonia." It has provided useful employment for many workers over a period of several months. The reconditioning has included the dismantling of the class-rooms and the gymnasium, which were used for the training of cadets, and the adaptation of the spaces for guardship purposes. On the machinery side the boilers have been re-tubed and the engines overhauled, while occasion has been taken to renew and refit the fuel, fresh-water, and other piping systems. The electrical equipment of the ship has been reconditioned, and the hull and fittings, including the rigging and the deck gear, have been overhauled, while the guns have been replaced.

Railway Wages

On Wednesday, August 16th, the Executive Committee of the Associated Society of Locomotive Engineers and Firemen met the General Managers of the four main line railway companies, when the union's claim for higher wages and improved conditions was again presented. The companies informed the union representatives that, in granting the increase in the minimum rate of the lowest-paid men, they had made the maximum concession which they considered could be justified in their present financial position. With regard to the claim for improved conditions it was suggested by the companies that it should be put forward again to the Railway Staff National Tribunal for consideration in the light of the altered conditions of to-day. On Tuesday, August 22nd, the Executive Committee of the Society of Locomotive Engineers and Firemen met in London, as did also a delegate conference of the National Union of Railwaymen. At the close of these meetings a letter was sent by the Society to the four main line railway companies and the Minister of Labour, stating that after giving very careful consideration to the replies from the branches regarding the policy on the programme items in dispute, the Executive Committee had adopted a resolution to the effect that, as the replies indicated a majority decision in support of strike action, the Committee had decided to call for a complete withdrawal of the labour of its members employed on the four main line group railways on and from midnight Saturday, August 26th. The conference of the National Union of Railwaymen reviewed the report of its negotiating committee and expressed its strong disapproval of the negative answer of the railway companies to its claim for a 50s. per week minimum adult rate. It noted that the companies were not averse to the claim being presented for consideration by the Tribunal, and believing that the case was an unanswerable one, it had instructed the Executive Committee to submit the matter to the National Tribunal without undue delay. The result of such submission is to be placed before a special general meeting.

A South Wales Road Scheme

The Minister of Transport has notified the local authorities and other interests concerned that he intends to proceed with an Order which will give final approval to a far-reaching scheme for new roads and bridges around Briton Ferry, Glamorganshire, at a cost of approximately £1,001,800. This scheme, we may recall, was the subject of a public inquiry which was held at Neath about two years ago. In the main the scheme provides for a diversion of the trunk road to the West, which now passes by a somewhat circuitous route through Briton Ferry, Neath, Skewen, and Lonlas. The proposed new road will be shorter and will avoid built-up and congested areas. It is proposed to construct a new road from Briton Ferry to Lonlas about 84ft. in width with provision for further widening to 120ft. The road will cross the tidal and navigable River Neath at a point not far distant from the site of the present ferry. A bridge over the Great Western Railway and the northern end of Briton Ferry dock, as far as Warren Hill, will be built, having a length of 900ft., and there will be another bridge having a length of 1700ft. over the River Neath. It will have a main span of 279ft. and a navigable height of 90ft. The cost of the road from Briton Ferry to Lonlas will probably be borne by the Government, and the Swansea arm of the scheme on the Jersey Marine Road, costing about £48,450, will be eligible for a 60 per cent. Ministry grant. A further grant of 75 per cent. has been promised by the Minister for the Jersey Marine Station, while the Swansea Corporation has been promised a further grant of 75 per cent. towards the cost of rebuilding the Harbour Trust bridges and the approaches to these bridges, which is expected to amount to about £180,000. When the scheme we have outlined has been carried through the distance by road from Briton Ferry to Swansea will be reduced from the present 11½ miles to 5½ miles, while the road distance from Swansea to Port Talbot, Cardiff, and the East will be shortened by some 6 miles.

Launch of H.M. Aircraft Carrier "Formidable"

The launch of the new aircraft carrier H.M.S. "Formidable" from the shipyard of Harland and Wolff, Ltd., at Belfast, on Thursday, August 17th, was of unusual technical interest, as about half-an-hour before the scheduled launching time the ship launched herself. The launch, we are in a position to say, was in every way successful, and subsequent examination of the ship has shown that no damage whatever was sustained. At twelve noon the hull began to move, and Lady Wood christened and dedicated the ship to her future service. Contrary to expectations, however, the timber work of the bow cradle did not move with the hull as it slid down the launching ways, but was left behind, and fell inwards, collapsing in front of the launching platform. Unfortunately, one person received fatal injuries from flying timber, but all the other injuries sustained were, we are informed, of a trifling nature. At the luncheon which followed the launching ceremony, speeches were made by Vice-Admiral Sir Alexander Ramsay, the Fifth Sea Lord, and Chief of Naval Air Services; Viscount Craigavon, the Prime Minister of Northern Ireland; Sir Kingsley Wood, the Secretary of State for Air; and Mr. F. E. Rebbeck, the chairman of Harland and Wolff, Ltd. In his speech Mr. Rebbeck urged the construction at Belfast of a large dry dock, which, he said, should be big enough to take the largest naval or mercantile vessel afloat. Belfast, he stated, was relatively the safest port in the United Kingdom, and the one thing needed for its complete equipment was a large dry dock. The waterway was straightforward and there was a good approach from the Irish Sea, whilst the site could be well protected from the surrounding hills. Referring to the present Admiralty work in hand at Belfast, which includes, besides the aircraft carrier, a submarine depot ship and an aircraft maintenance ship, Mr. Rebbeck said that he had been given to understand by the Lords of the Admiralty that the Harland and Wolff shipyards would be kept for the larger ships, for the construction of which they were so well equipped.

A History of Rotary Engines and Pumps

PART II.—No. V

(*Continued from page 176, August 18th*)

HELICAL GEAR MACHINES (*continued*)

COMPRESSED air is used as a means of transmitting power in carrying out a variety of works. It competes, for instance, with electricity in coal mines, particularly those of a gassy nature, on account of the relative safety accompanying its use, and it is frequently used for other mining and tunnelling work, since the exhaust from the machines helps to ventilate and, if necessary, cool the workings. On few civil engineering jobs is there no work which is not best performed by the use of compressed air.

In these circumstances and particularly since at the beginning of this century electrical appliances were still in their infancy, it was natural that attempts should have been made to devise air motors capable not only of working small tools, but even of developing considerable power for driving ventilating fans, drainage pumps, winches, scraper loaders, and coal cutting and conveying machinery. The double helical gear motor seems to have been first suggested in 1896 (Patent No. 28,737) by an American, Charles Backstrom. His design is illustrated in Fig. 48. Each rotor was to be built up out of numerous discs mounted together on the same shaft. Each disc was to be formed with teeth and they were to be arranged so that the teeth on adjacent discs were successively out of phase along the axis, with the result that an approximation to a helical shape was attained. For some reason Backstrom preferred that the discs should vary in thickness, the thickest being situated at the outer ends of the compound rotors and the thinnest at the centre. "By reason of this construction," says the specification, "the expansion of the steam and consequently the work done by it is effected in the shortest possible time and . . . the smallest possible portion of the cylinders or drums is unbalanced at any time by unequal pressures."

At that time, of course, helical gearing had not been developed for other purposes, and machine tools for cutting such gearing probably did not exist. So Backstrom was forced to adopt a construction that only approximated to the true helical form. Modern double helical machines operate upon principles originally laid down by another American, J. H. van Deventer in Patent No. 12,623 of 1911. By that time, of course, the development of helical gears for other purposes had made available tools capable of the necessary accuracy. Little radical alteration of the basic design has been made since that date, but the use of materials better fitted to stand up to the work or more amenable to the machining processes, combined with an increasing refinement of design, has led to a steady improvement in performance.

Photographs and drawings, reproduced in Figs. 49 to 52, illustrate a motor, adapted for incorporation in a coal cutter, as made by Mavor and Coulson, Ltd., of Glasgow. The air enters through the port seen at the apex of the division between the bores on the underside of the rotors—Fig. 50. Fig. 52 represents diagrammatically the appearance of the rotors when looked at from the underside, *i.e.*, from the air inlet. Triangular spaces, such as Z, Y, A, B, are formed by the sealing of the tooth spaces in one rotor by the teeth of the other, and it will be seen that the size of the spaces so formed will increase as the rotors turn away from each other. The inlet port is shown dotted in such a position that spaces A and Z are both receiving air from it. Space Z is just being formed and space A has almost moved past the opening. Spaces Y, X, B, C, &c., are clear of the port and are receiving no more air, but the spaces remain sealed until the teeth forming them come out of engagement at their ends. As each tooth passes over the port, it traps a volume of live air in the space in front of it, and this air, in order to expand, enlarges the compartment containing it in the only way possible, that is, by turning the rotors as shown. For each tooth the point of cut-off arrives when its front edge passes over the lower edge of the inlet port, and expansion continues from this point until release occurs, when the ends of the meshing teeth concerned come out of engagement with each other at the ends of the rotors. The cut-off point can be adjusted by varying the size of opening between the bores, but this adjustment also controls the amount of air admitted, and hence the power developed. Release is normally through the ends of the teeth as they come out of engagement. Should earlier release be required, the segment of the bore which embraces the tips of the teeth may be cut back sufficiently to effect it.

The firm considers that cast iron is the best material for both rotors and casings. Strong and rigid shafts with bearings of ample size are provided to maintain the rotors accurately in position. Each rotor is clamped at one end against longitudinal movement, and one is adjustable length-

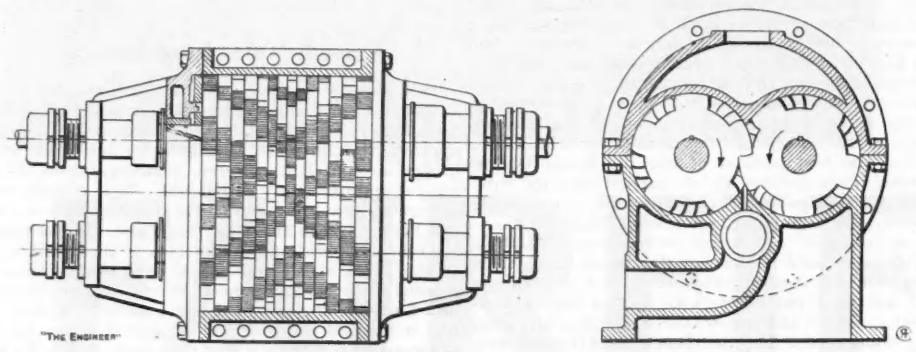


FIG. 48—BACKSTROM'S HELICAL GEAR MOTOR—1896

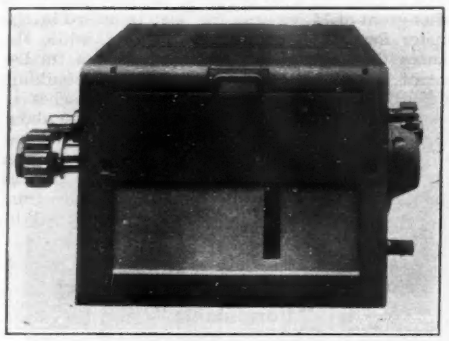


FIG. 49—AIR MOTOR—M. AND C.

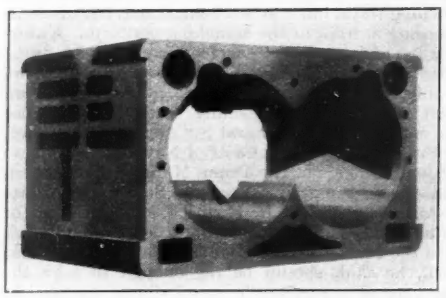


FIG. 50—CYLINDER OF AIR MOTOR—M. AND C.

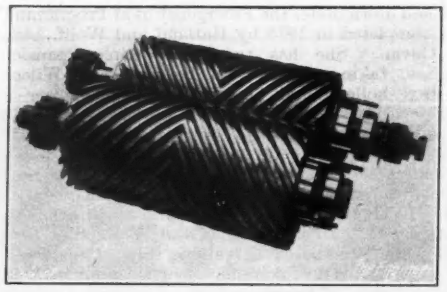


FIG. 51—ROTORS OF AIR MOTOR—M. AND C.

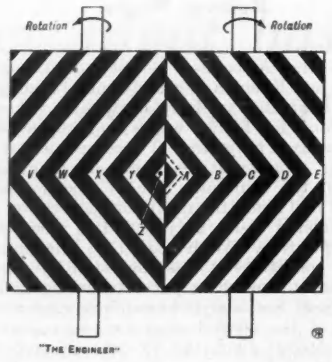


FIG. 52—DIAGRAM OF UNDERSIDE OF ROTORS —M. AND C.

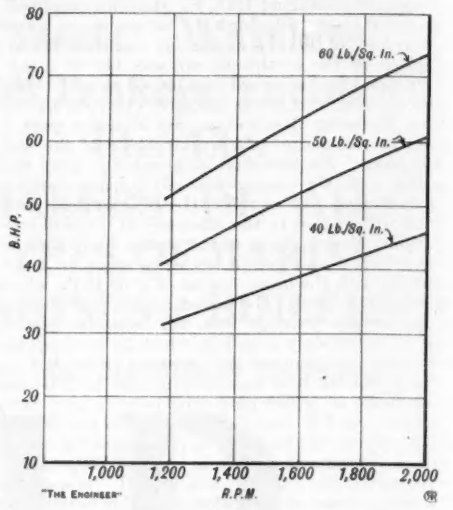


FIG. 53—POWER DEVELOPED BY AIR MOTOR —M. AND C.

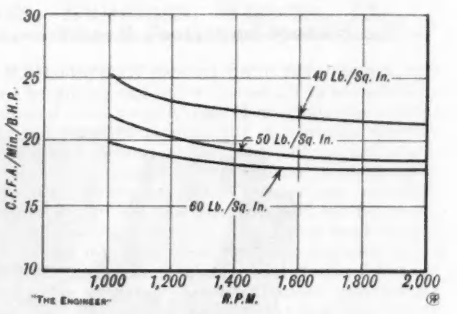


FIG. 54—AIR CONSUMPTION OF AIR MOTOR —M. AND C.

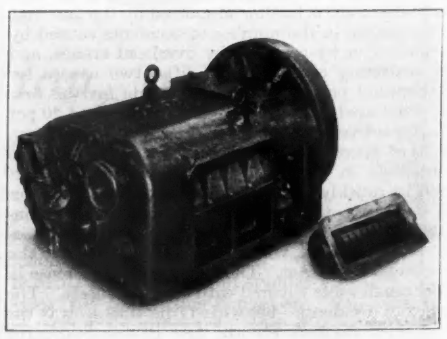


FIG. 55—"SPIRO" AIR TURBINE—B.J.D.

wise to ensure correct meshing. The end covers are carried on spigot registers. The machine is non-reversing, but as a drive may be taken from either shaft, it is not difficult to arrange a reversing gear, and it is immaterial which end of the machine the drive is taken from. The illustrations show that a drive may be taken from both ends, if necessary. A filter is incorporated to ensure that

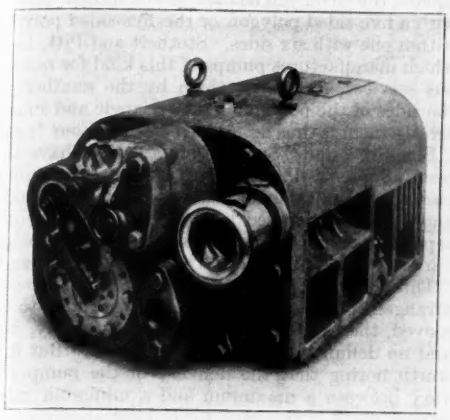


FIG. 56—AIR TURBINE WITH GOVERNOR COVER REMOVED—B.J.D.

the air supply to the rotors is cleaned and sliding doors are fitted over the exhaust louvres to exclude dirt which might find its way into the machine when standing idle. When the air supply is cut off, the inertia in the rotors keeps them running, and they create a vacuum in the inlet port which sets up undesirable vibration. A relief valve is accordingly fitted to admit atmospheric air to the

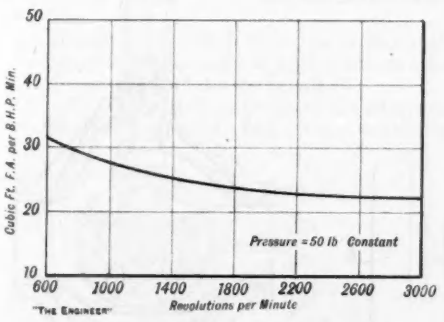


FIG. 57—AIR CONSUMPTION OF "SPIRO" TURBINE —B.J.D.

inlet port. The accompanying curves, Figs. 53 and 54, illustrate some of the characteristics of the machine and the efficiencies which may be obtained.

Machines made by British Jeffrey-Diamond, Ltd., of Wakefield, are known as "Spiro" air turbines, and examples are illustrated in Figs. 55 and 56, the latter showing a machine with the governor cover removed.

From these pictures it will be seen that the arrangement is compact and that there is an absence of any overhanging or external parts. These features are of importance because the machines have frequently to work in confined spaces in the hands of unskilled labour and may need to be moved from place to place as the work proceeds. The machine is designed and built as a complete unit, with a reduction-reverse gear-box cast integrally with the rotor cylinder. The end covers and the rotor bearings are located by spigot and faucet registers to ensure rigid alignment of the whole machine and the correct setting of the rotors in the cylinder bore. No dowels whatever are used.

Cylinder casings are made in cast steel and a close-grained nickel-iron is used for the rotors on account of its machining qualities and freedom from blow-holes. The rotors are carried in double-row, self-aligning roller bearings. Each complete rotor and shaft is dynamically balanced for smooth, vibrationless running.

From the inlet flange the compressed air passes firstly through a large strainer which can be easily withdrawn for cleaning, and is then "sprayed" with lubricant before passing through the throttle valve to the inlet port beneath the rotors. The atomised oil both lubricates the throttle valve and protects the rotors against rust. To prevent rusting during standing periods, an auxiliary oil chamber at the top of the cylinder casting feeds a small quantity of oil directly on to the rotor teeth. This device only operates when there is no exhaust pressure.

Reversing is effected through a hand wheel at the control end of the turbine. Splash lubrication is arranged for the gears and the speed controller and effective oil troughs cast integrally with the cylinder and gear case collect a supply of oil and direct it through channels to the bearings. The reduction-reverse gear case forms a substantial sump, which is carefully finned to dissipate heat, and has an accessible drain plug on either side.

The latest turbine is quieter than previous designs and by a special arrangement of the exhaust release air vibrations are much reduced. The exhaust ports are effectively streamlined and their position has been carefully planned to give ample exhaust area, but to prevent unauthorised access to the rotors or the ingress of foreign material into the cylinder. The velocity of the exhaust air is considerably reduced, obviating the dust problem attendant on previous designs of compressed air turbines, and the design helps to prevent stoppages through freezing where compressed air containing a good deal of moisture is in use. The "Spiro" air turbine is made in several sizes up to 40 H.P. with air at 50 lb. per square inch pressure.

Although compressed air turbines have steadily improved in design and efficiency, until recently little attention was paid to the suppression of the noise they create when working. Mechanical improvements in gears and bearings, &c., have helped slightly, but the exhaust release is now, as always, the chief source of noise in working.

British Jeffrey-Diamond, Ltd., recently evolved a silencer for the "Spiro" compressed air turbines which is simple and efficient and can be adapted to fit any new type machine. As shown in Fig. 55, where it is seen removed, it is a compact unit that fits directly over the exhaust ports. It is designed in the form of a volute chamber pierced by a central tube through which the spent air is finally released. The silencer is lined with an asbestos blanket which not only deadens the resonance, but also reduces freezing and the formation of frost and ice.

A graph reproduced in Fig. 57 shows the air consumption of the latest 15 H.P. machine when supplied with air at 50 lb. per square inch pressure.

INTERNAL GEAR MACHINES

The idea that the internal gear mechanism might be adapted to work as a rotary engine or pump seems to have first occurred to an American, as related in the first part of this series. The design has been found of value and to-day internal gear machines are made in capacities which are very large relatively to those usual among rotaries.

1901/18,551: *Foley*.—This amusing engine was invented by Foley in 1901, and is a curious hybrid, half Concealed Reciprocator, half Internal Gear. From Fig. 58 it will be seen that instead of having internal teeth the outer wheel is made in the form of a number of radially disposed cylinders. Within the outer wheel there rotates an inner wheel, with five radial spokes, about an excentric centre. The end of each spoke is shaped to engage with the undersurfaces of pistons working in the cylinders. In operation steam was to be admitted to one of the two inlet spaces A according to

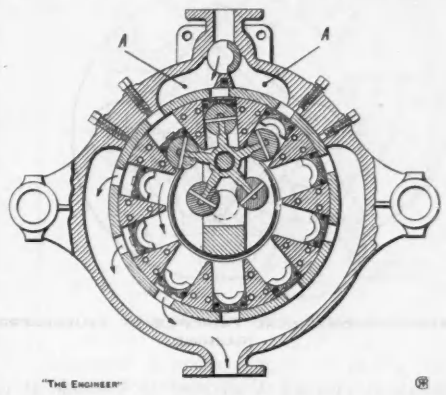


FIG. 58—FOLEY—1901

which direction it was desired the machine should turn. It gained access to the cylinders and drove the pistons inwards, the resulting reactionary forces causing both inner and outer wheels to rotate. After the point of cut-off was reached a period was allowed during which the steam might expand. When the exhaust opened the pistons were to be returned to the outer ends of the cylinders by centrifugal force.

1915/9359: *Lilley*.—Until 1915 all the internal gear mechanisms suggested seem to have been of that form in which a crescent-shaped block or abutment is interposed, between the two wheels on the side furthest from the point of engagement of the teeth. But in 1915 a simpler form of construction was suggested by Lilley. His machine, which is illustrated in Fig. 59, had cycloidal teeth, and the outer rotor had one more tooth than the inner, with the result that besides the meshing of teeth on one side there was contact between the heads of teeth on the other, and a seal consequently existed between the inlet and outlet sides without the need for the crescent block. The teeth were to be shaped to a rolling

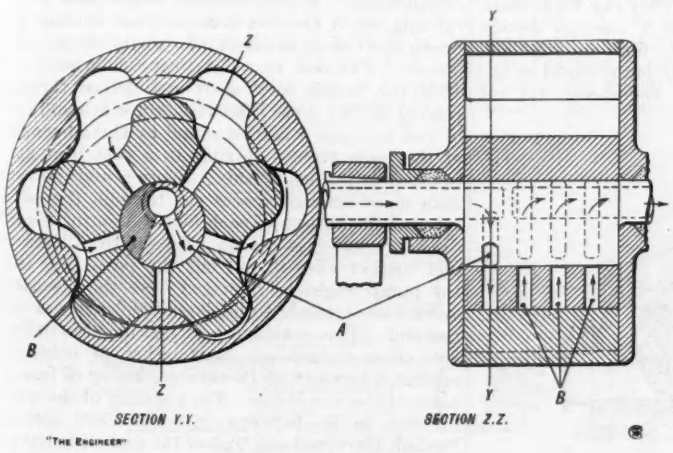


FIG. 59—LILLEY—1915

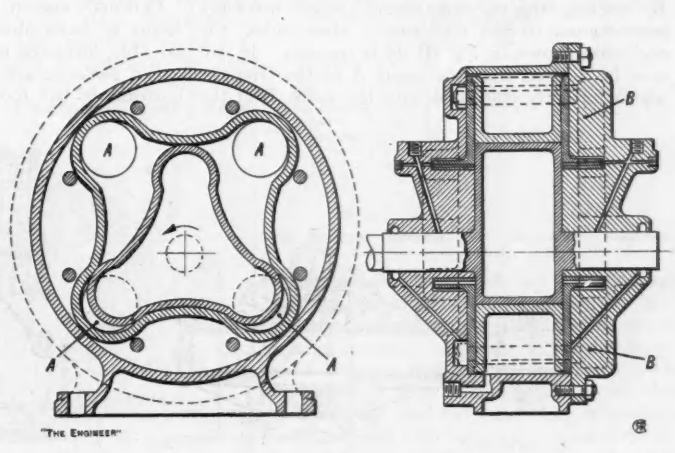


FIG. 60—FEUERHEERD—1919

circle having a diameter intermediate of the diameters of the pitch circles of the inner and outer wheels. The circles referred to are shown dotted in the drawing. In modern machines both wheels are caused to revolve. Lilley, however, suggested the alternative arrangement in which the outer wheel remained stationary whilst the

inner one was freely mounted on an excentric. By that means the same relative motion between the two wheels is produced.

Whatever the precise arrangement the inner rotor was to be mounted on an excentric pin of large diameter in which inlet and discharge passages were to be formed. The inlet passage terminated in a single wide-

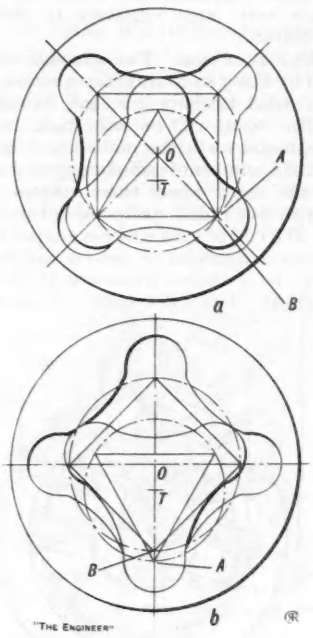


FIG. 61—GEOMETRICAL PRINCIPLE OF FEUERHEERD'S MACHINE

mouthed opening A adapted to coincide at one time with not more than one of several radial passages in the rotor leading to points between its teeth. But the outlet passage had three much wider openings B, each adapted to coincide with similar rotor passages two at a time, and was situated on the other side of the pin. The arrangement was such that if steam were used to drive the machine use could be made of its expansive powers.

1919/130,839: *Feuerheerd.*—Modern pumps made by Stothert and Pitt, Ltd., of Bath, are made in accordance with principles laid down by Feuerheerd in his patent of 1919. In general appearance there is not very much difference between the machines proposed by Lilley (Fig. 59) and by Feuerheerd (Fig. 60). But, in fact, the geometry is entirely altered. Whereas Lilley's machine works truly as a gear mechanism, Feuerheerd's is founded upon the properties of a polygon rotating in and with another polygon with an additional side. The two polygons have sides of equal length and the distance between their centres is so adjusted that in certain angular positions a side of each exactly coincides with that of the other. Conditions existing when a triangle and a square are so arranged are shown in Fig. 61 (*a*), the respective centres being designated T and O. By rotating both polygons through angles inversely proportional to the numbers of their sides, the condition shown in Fig. 61 (*b*) is reached. It will now be noticed that the point A of the triangle, which formerly coincided with the point B of the square, still remains on the radial line from the centre of the square through point B. Feuerheerd made use of this geometrical fact by constructing parts of circles with the points of the triangle as centres and forming on the corners of the square lobes which had straight sides parallel to the radial lines from the centre of the square. These lines were set apart by a distance equal to the diameter of the circles on the points of the triangle. Thus, as the two polygons rotated, a pumping "in and out" action occurred whenever a point of the triangle penetrated a lobe on the square. The lobes at the corners of the square were, and still are, connected by curves which are generated by the relative motion of the two parts during the remainder of the circuit when, of course, the corner of the triangle is no longer moving radially to the square. They are neither true cycloids nor circles, but approximate very closely to the latter. Investigation reveals that this construction, if the mechanism is to operate correctly, requires that one of the two polygons shall rotate at an angular velocity which, though very nearly, is not quite uniform. The discrepancy is, however, so slight as to impose no limitations on the use of the machine.

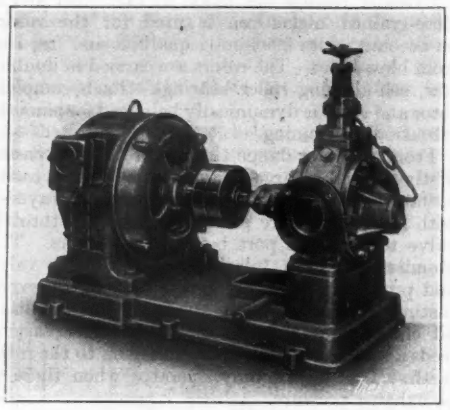


FIG. 63—FUEL OIL SUPPLY PUMP—STOTHERT

Curiously enough, neither Lilley nor Feuerheerd seems to have observed that it was not merely possible, but even preferable to form the inlet and outlet passages actually in the outer wheel at the bottoms of the tooth slots. Feuerheerd did not propose the same arrangement of passages as Lilley. He carried the outer member on discs at each end, Fig. 60, and cut a port A through one of the discs into each of the lobes. As the rotor turned these ports co-operated with semi-annular inlet and outlet channels B in the stationary casing at the back of the disc. Like Lilley, Feuerheerd also suggested an arrangement in which the outer rotor remained stationary, whilst the inner rotor turned. In that case the inner rotor was mounted freely on a crank and as the crank turned, it "walked" around the outer rotor, performing, in the case of the triangle and square, one complete revolution backwards for every three forward turns of the crank.

Instead of the triangle revolving in and with the square, the latter can be rotated in a similar manner with a five-sided polygon or the five-sided polygon within one with six sides. Stothert and Pitt, Ltd., which manufactures pumps of this kind for numerous services, designates them by the numbers of the sides of the polygons. The triangle and square arrangement is thus designated "Three-Four"; and "Five-Six" and "Seven-Eight" designs have also been adopted. Pumps of this kind have proved particularly suitable for dealing with viscous fluids, and materials handled by existing pumps include asphalt, bitumen, tar, molasses, glucose, paint, varnish, foodstuffs, &c. The choice as between "Three-Four," "Five-Six," or other pump arrangements is dependent upon the fluid to be moved, the temperature conditions, viscosity, &c., and no definite rules can be laid down. But it is worth noting that the delivery of the pump will vary between a maximum and a minimum value as each tooth of the inner rotor penetrates into and leaves a lobe on the outer rotor. It follows that the delivery of machines with a greater number of teeth will be more regular, other things being equal, than that of machines such as the "Three-Four." The size of the pumping chambers, however, becomes smaller in relation to the bulk of the machine as a whole, but the speed of rotation can be increased.

A typical "Five-Six" pump is shown in the drawing Fig. 62. It is a large machine intended for oil loading and bunkering, a service in which, as a result of variations in the quality of oil and in climatic conditions, the actual duty may alter considerably. A conservative design and a low running speed are therefore adopted so that the pump shall work satisfactorily whatever the conditions. The cast iron inner rotor is keyed to a 40/45-ton tensile steel shaft and driven through gearing at 73 r.p.m. The outer rotor is also made of cast iron and is carried round by the movement of the inner rotor. It runs in a cast iron liner inserted in the main body. Suction and delivery take place through spaces cut through the outer rotor at the bottom of each lobe. A spring-loaded discharge valve is placed between the discharge and suction sides to prevent the possibility that the pump might be damaged were the discharge valve inadvertently to be closed whilst it was still running. This machine was specified to deliver 350 cubic metres per hour either of crude oil against a pressure of 12 atmospheres or of fuel oil against 10 atmospheres. The viscosity of the crude oil was to lie between 285 and 2200 seconds Saybolt Universal and that of the fuel oil to have a maximum of 7000 seconds to the same standard. The performance of the pump when running at 74 r.p.m. is indicated in a graph in Fig. 65.

Another pump is illustrated in Fig. 63. It is similar to pumps installed on the "Queen Mary" and "Mauretania" and is designed to supply oil to an oil-burning installation. The "Seven-Eight" pump is, in the case illustrated, direct coupled to a 3 H.P. motor, but had the oil been of a heavier variety, requiring the pump to run at a

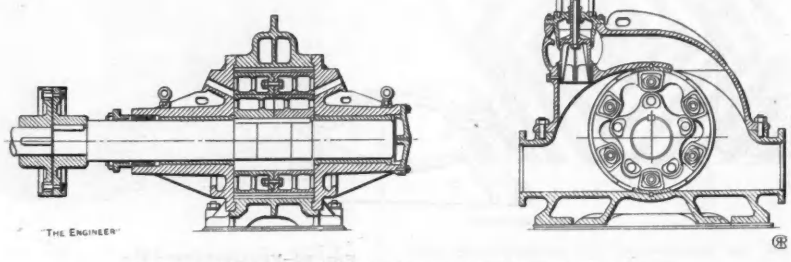


FIG. 62—OIL LOADING AND BUNKERING PUMP—STOTHERT

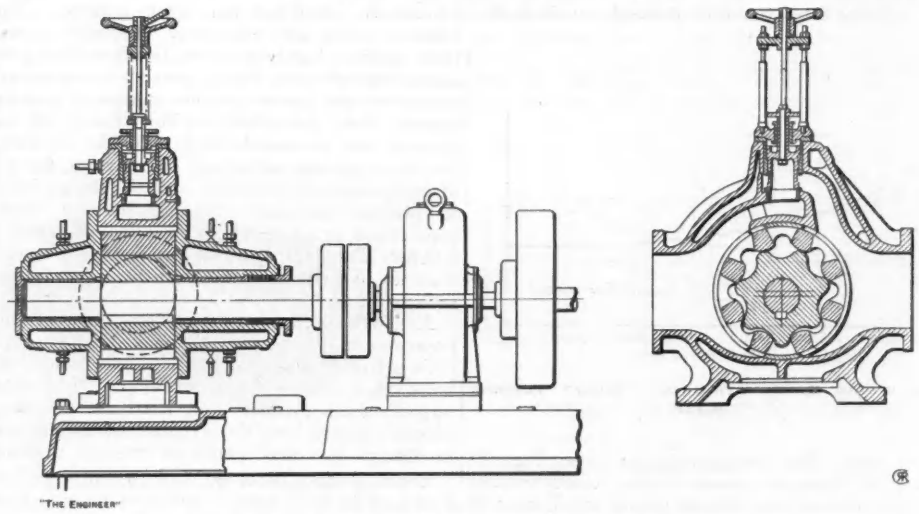


FIG. 64—ASPHALT AND BITUMEN PUMP—STOTHERT

lower speed, gearing would have been interposed. An output of 10 tons per hour of light boiler fuel with a specific gravity of 0·95 and a viscosity of 1500 seconds Redwood No. 1 is attained when the machine is running at 720 r.p.m. and delivering against a pressure of 20 lb. per square inch. The pump is wholly made of high-grade cast iron with the exception of the steel shaft.

The design and materials of the pumps made by Stothert and Pitt, Ltd., vary considerably in accordance with the precise requirements of the duty and the characteristics of the material to be moved. A "Seven-Eight" pump for asphalt and bitumen compounds is illustrated in Fig. 64. The firm has built many pumps for this service and has manufactured them to deal with material only just sufficiently warm to become fluid enough for pumping and to pump with fluid at temperatures up to 400 deg. Cent. as encountered in oil refining works. For oil refining and distillation the pump is frequently required to draw against a vacuum within 20 mm. of absolute. The particular pump illustrated in the drawing has a jacketed body, through which steam or hot water can be circulated and the jackets extend around the spring-loaded relief valve. Where temperatures exceeding 200 deg. Cent. are concerned cast steel may be the material used, but normally cast iron is employed for all parts except the shaft. Pumps of this kind have been supplied for deliveries up to 250 cubic metres per hour, capable of handling

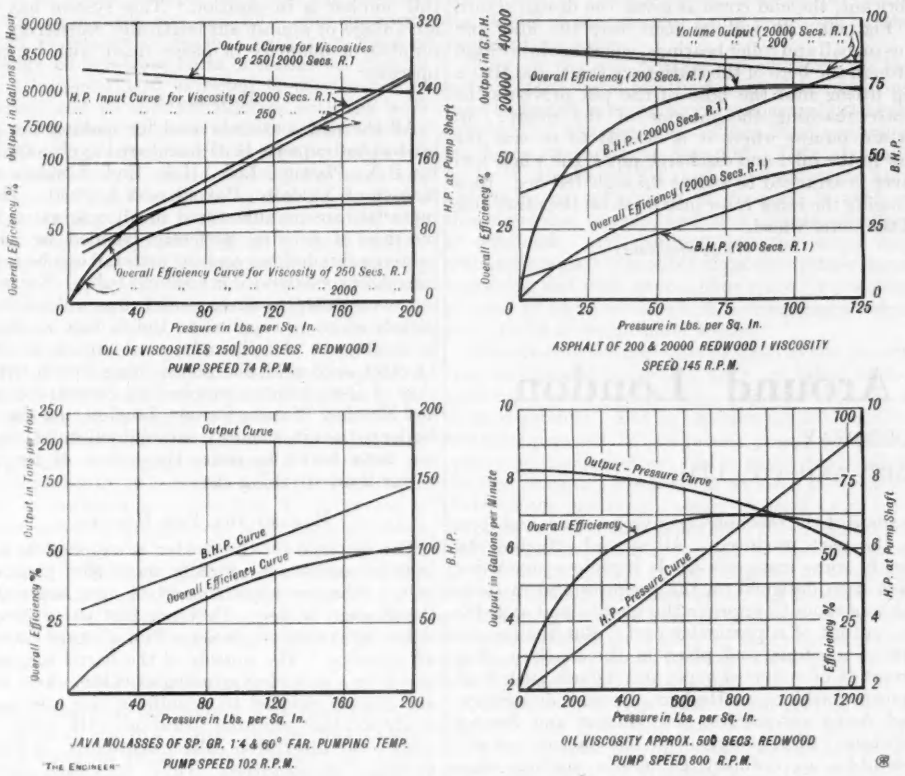

Output in Gallons per Hour
Overall Efficiency %
H.P. at Pump Shaft
Output Curve for Viscosities of 250/2000 Secs. R.1
H.P. Input Curve for Viscosity of 2000 Secs. R.1
250
Overall Efficiency Curve for Viscosity of 250 Secs. R.1
2000
Pressure in Lbs. per Sq. In.
OIL OF VISCOSITIES 250/2000 SECS. REDWOOD 1
PUMP SPEED 74 R.P.M.
Output in G.P.H.
B.H.P.
Volume Output (20000 Secs. R.1)
200
Overall Efficiency (200 Secs. R.1)
B.H.P. (20000 Secs. R.1)
Overall Efficiency (20000 Secs. R.1)
B.H.P. (200 Secs. R.1)
ASPHALT OF 200 & 20000 REDWOOD 1 VISCOSITY
SPEED 145 R.P.M.
Output in Tons per Hour
Output Curve
B.H.P. Curve
Overall Efficiency Curve
JAVA MOLASSES OF SP. GR. 1·4 & 60° FAR. PUMPING TEMP.
PUMP SPEED 102 R.P.M.
Output in Gallons per Minute
Output - Pressure Curve
Overall Efficiency
H.P. - Pressure Curve
Efficiency %
OIL VISCOSITY APPROX. 500 SECS. REDWOOD
PUMP SPEED 800 R.P.M.
THE ENGINEER

FIG. 65—CHARACTERISTICS OF VARIOUS PUMPS—STOTHERT

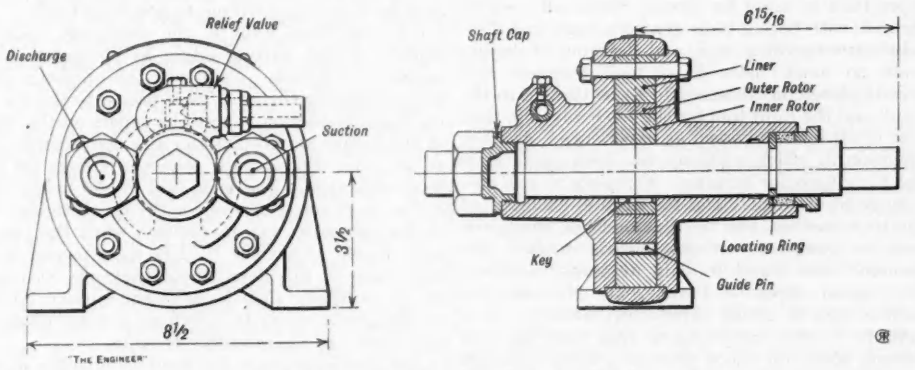


FIG. 66—HIGH-PRESSURE PUMP—STOTHERT

asphalt, bitumen, and other compounds handled by oil companies and also cable compounds and similar materials. The performance of the particular pump illustrated is indicated by one of the graphs in Fig. 65.

Many more examples of the internal gear pumps made by Stothert and Pitt, Ltd., could be described, since the firm is probably the largest supplier of large rotary pumps in this country. We intend, however, to content ourselves with a reference to the molasses pumps made by the firm. The viscosity of molasses as pumped is frequently very high indeed. In the case of a large oil engine-driven unit recently supplied to deliver 200 tons per hour of 1·4 specific gravity Java molasses it was equivalent to 150,000 seconds Redwood No. 1 at the pumping temperature of 60 deg. Fah. The discharge pressure in this case is 125 lb. per square inch and the machine runs at 90 r.p.m. Large pumps for this service are, like the other machines already described, made of cast iron throughout, except for the steel shaft and bronze bearings. But in the smaller sizes bronze is sometimes adopted for the outer rotors. The molasses tend to build up on the outer rotor and bronze has been found more resistant to fracture from this cause than cast iron. In larger pumps it is the general practice to wash out the pump with water periodically, with the object of preventing the building up of the

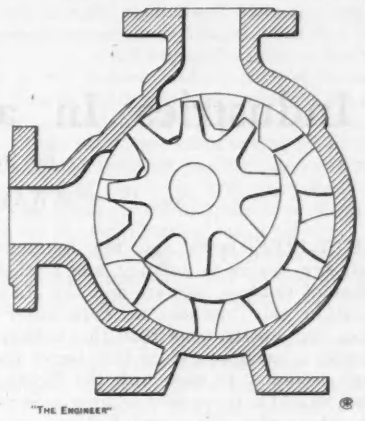


FIG. 68—"ROTAN" PUMP—JOBSON

molasses. A graph reproduced in Fig. 65 shows the characteristics of the 200-ton pump mentioned above.

That internal gear pumps are suitable only for comparatively low pressures is disproved by another graph reproduced in Fig. 65. The pump concerned handles oil of 500 seconds Redwood No. 1 viscosity and runs at 800 r.p.m. It is illustrated by the drawing Fig. 66, from which it will be seen that the design is considerably modified for this high pressure service. Delivery and suction no longer take place through slots in the outer rotor. The fluid is introduced and delivered from and to ports at the side of the working chamber. Comparison with the other drawings will show other modifications.

1925/238,620: *Stone and Paramor.*—The pump patented in 1925 and subsequently known as the

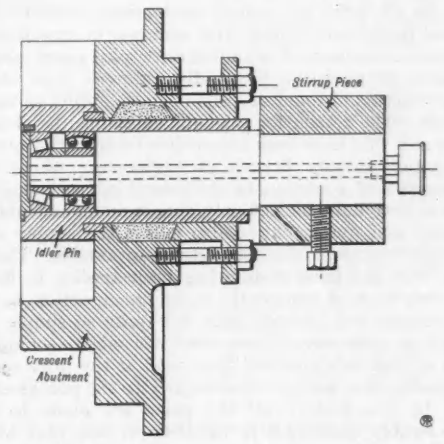


FIG. 69—END COVER OF "ROTAN" PUMP—JOBSON

Stone-Paramor, was made by J. Stone and Co., Ltd., of Deptford. Its manufacture has only recently been given up. The machine was of that form in which a crescent-shaped block is interposed between the rotating members, and it is illustrated in Fig. 67. The shape of the teeth was cycloidal, and the outer ring consisted of six bronze or cast iron sections A assembled on steel studs between steel end plates. The rotor so formed was machined to rotate freely within a hard nickel bronze liner B fitted to the pump casing, and was a close running fit against the end covers. The inner rotor C, which had four teeth, was usually made of cast iron. Accurately turned shoulders engaging with recesses in the end covers located it in the correct working position, and it was keyed to a high tensile steel shaft carried at each end in self-aligning ball bearings. Cast iron was the

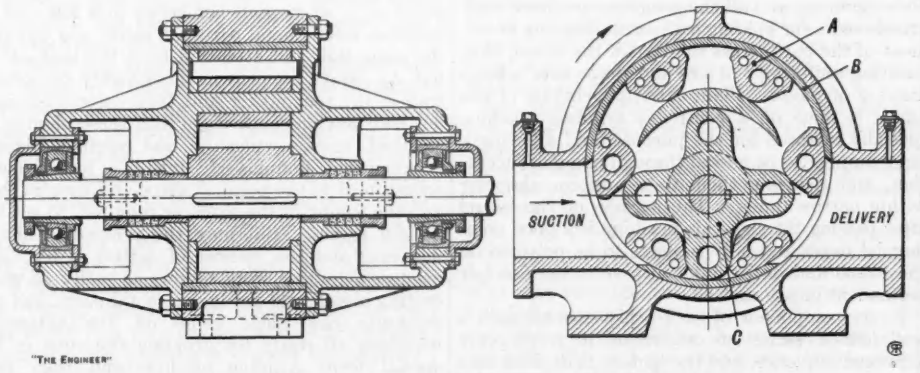


FIG. 67—STONE-PARAMOR PUMP—STONE

material generally used for the casing. Stone-Paramor pumps were made in a range of sizes giving capacities from 3 to 550 tons per hour at 500 and 100 r.p.m. respectively, when operating on such a fluid as heavy Mexican fuel oil. With lighter fluids higher speeds could advantageously be employed.

Another modern internal gear pump is that known as the "Rotan" (Fig. 68), made by Jobson and Beckwith, Ltd., of 104, High Holborn, London, W.C.1. The design of this machine is notable for its simplicity. The outer rotor is overhung on the end of the driving shaft, and the inner rotor, which has more or less straight-sided teeth, runs on an idler pin mounted in a bearing in the end cover of the pump. The crescent-shaped abutment is made as an integral part of the end cover. Pumps with capacities from 120 up to 46,200 gallons per hour, running at 1000 and 250 r.p.m. respectively, are made. In addition to their use for moving petrol and other spirits, Rotan pumps are also employed for operating with milk. When, as in that case, it is desirable that the fluid to be pumped shall not become contaminated with lubricant, the end cover is given the design shown in Fig. 69. It will be seen that the idler pin runs on ball and roller bearings, which are lubricated through the bore of the stationary shaft, and that a cap fitting into the bore of the pin prevents the grease reaching the interior of the pump. In certain pumps where it is desired to reverse the flow in the inlet and discharge pipes, the whole end cover is arranged to swivel through 180 deg., thus bringing the inner rotor into mesh on the other side of the outer wheel.

(To be continued)

Industries In and Around London

By JOHN HOLLOWAY

No. IV—CONWAY STEWART AND CO., LTD.

THIRTY-FIVE years ago the fountain pen industry was in its infancy, and at that time the firm of Conway Stewart and Co., Ltd., was engaged in this business in Paternoster Row, London, but by the year 1920 this industry had developed to such an extent that larger premises became necessary to cope with the demand, and the firm moved to its present address in Shoe Lane, E.C.4, where the offices and factory are to-day combined and housed in the same building in this busy part of London.

Some idea of the progress the industry has made in recent decades will be gathered from the fact that the yearly output of completely manufactured fountain pens from this company alone is approaching the million mark, and the demand continues to increase.

But while the mention of an output of one million finished pens per year gives an impression of great production, it by no means conveys a true estimate of the work involved, for every pen requires at least 100 major operations in the process of manufacture from the raw material to the finished product, so that in total there are 100 million essential processes dealt with in the factory every year, not to mention minor operations such as adjustments and testing, as found necessary when each part reaches the inspection stage.

In all forms of modern mechanical production, and particularly where large numbers of repetition parts are concerned, a limit in error, plus and minus, must of necessity be rigidly enforced, and the production of fountain pens is no exception to the rule. The reason for this will, of course, be clear to any who have been responsible for quantity production in any branch of engineering where a number of components are assembled to make a complete unit, for not only does it make assembly easy and quick, but it also makes the supply of replacements, without adjustments, possible. That is why the limit system has been applied to the production of apparently so simple an article as a fountain pen, though it is not quite so simple a job as some may think, when it comes to making a million in a specified time, and at the price and quality that will prove attractive to the purchaser.

In this factory all the parts are made to a tolerably close limit in variation of size, that will admit of ready assembly and replacement of any part, should that ever become necessary, but there are parts where tolerance is practically nil. For instance, the ink feed is made a perfect sliding fit in the bore of the nib holder, and the care taken to ensure a leak-free fit between these two parts is reminiscent of the extraordinary precautions that have to be taken to produce a perfect fit between the plunger and barrel of an oil engine fuel pump.

The Factory

Electric current for factory drive and light is generated on the premises, but current is also laid on at company's mains and may be used whenever required.

The equipment of the factory has many interesting features that are special to this particular branch of business, and the work of the engineer is plainly seen in the many mechanical devices and operative attachments that have been fitted to some of the machines to give precision and form to the part produced. All special attachments, and in some instances whole ingenious machines, have been designed on the premises and made in the tool room to improve the quality and expedite the output of a particular part. But the general run of machine tool plant in the machine shop proper is of standard type, and include such well-known machines as Herbert, Browne and Sharp, and Acme automatics, and Warner and Swasey capstans. This section of the factory closely resembles an ordinary engineer's machine shop engaged in the production of turned, bored, and screwed small metal components, though the small tools used for cutting the material from which the familiar fountain pen is largely made, differ in many respects from the tools used for cutting metals, as owing to the clinging nature of the plastic material, it has been found necessary to design tools with sharper angles and wider clearances than is usual for metal. Especially is this the case with boring tools, reamers, taps, and dies. All theory regarding angle and clearance of cutting tools, so much beloved by tool designers and investigating committees, had to be thrown to the wind, and the right tool for the job evolved in that best of all schools known as experience. Another direction in which a change has been made is in the tools used for turning. Formerly it was customary to use a diamond for turning ebonite and similar materials, but the diamond has now given way to tungsten carbide cutting tools. The diamond was found to chip at times, and was proving an expensive luxury, but the tungsten carbide tool is giving satisfactory results. It is perhaps a little surprising to find that the best cutting speed for these plastics is lower than the speed for cutting metals, though it is more a question of surface finish than of keeping a keen edge on the tool that governs the cutting speed in this instance.

Special grinding machines have been designed to assist in giving rapid and accurate production, and on some parts grinding is one of the major operations. A carborundum grinding wheel of a special grit and grade is used both for form and plain grinding, and all the machines are fitted with attachments for holding and controlling the movement of the part across the face of the wheel, thus ensuring uniformity of size and shape over a large number of pieces. Plain external grinding of the barrel is done on a centreless grinding machine specially adapted for the purpose, and allowing a large number to be passed through in quick succession, and reducing them to a uniform diameter within narrow limits. The surface of the barrel after passing through this machine is a good commercial finish and only requires to be polished on the calico and down buffs to give it the familiar permanent glossy surface.

Every component of each pen passes through a well-defined series of operations in a properly arranged sequence, and the factory is divided into departments, each of which deals with a particular part, or a given set of operations, but all ultimately converging on the assembly department, where the final inspection and grading takes place. There is no confusion or delay in getting a sufficient quantity of each component through to the assembly room to make completed pens, as the flow of parts is regulated by the adoption of the batch system, a batch of any part consisting of one gross. The number in the batch is further regulated by the use of special trays, each tray being arranged to accommodate one gross of a part, and to support them in such a way as to show at a glance if the full number is in position. This system has the advantage of almost automatically registering the number or quantity of pieces dealt with by each operator.

Materials

All the raw materials used for making the pen holders and caps are British and are largely supplied by B.X. Plastics, Ltd., Hale End, London, the makers of Xylonite, Bexoid, and Lactoid. These materials are manufactured in all colours or any mixture of colours, perfectly blended in many patterns and designs, and the material can be rolled into sheets or extruded in rods and tubes. For making levers, compression bars, and clips, rolled gold or nickel, which is supplied to the factory in strips, is employed. All the nibs used are made from 14-carat solid gold, the points being tipped with a chip of Osmi-iridium, supplied by Messrs, Johnson and Matthey, Hatton Garden, London, and the ink feeder to the nib is made from solid vulcanite, which has been found to resist the action of the ink better than anything else.

Making the Pen Holder

The material for the holder is supplied in rods or tubes, which are normally about 40in. long, and have a diameter approximately $\frac{1}{2}$ mm. larger than the finished holder. They are first cut to length either by sawing or parting off on a rotary cutting-off machine. The outside of the barrel is ground to size on a centreless grinding machine, where they are quickly reduced to a uniform size and made ready for the polishing operation. On page 212 there is illustrated the centreless grinding machine in operation. They are then passed in gross lots to the capstan lathes to be bored and screwed. Another engraving shows a group of these machines engaged on this process. The machines are run at a moderately high speed, generally about 900 r.p.m. for drilling and boring a $\frac{1}{4}$in. hole, and, as already mentioned, the drills, reamers and screwing dies are made with sharp angles and large clearance to allow the cuttings to get away freely. A feature of these tools is the extremely narrow landing of the cutting edges as compared with metal-cutting tools. Following this operation, the tray containing the gross lot is passed to the grinding machine section, where the tapers on the ends of the holder are ground and also the rounded tip at the solid end, and the crosswise groove for the lever clearance. The open end of the holder has a four start screw thread for the quick tightening of the protective cap in position when the pen is not in use. After the holders have passed final inspection in this department they are conveyed to the polishing shop to have the surface dollied to the glossy finish to which all are accustomed, and thence to the assembly benches.

The protective caps are made from tubes in the same material and generally of the same colour as the holders. The process is also very similar, but in this case two internal screw threads, the four start thread to match the holder and the single start thread to take the end plug by which the pocket clip is held in position.

Made from solid rod material, the cap plugs are turned, bored, and screwed on Herbert or Brown and Sharpe automatic machines, the setting up of which is in all respects similar to that followed in factories where metal parts are made, and requires the same skill and attention from the tool setter, but, as always happens in these highly specialised trades, the tool maker and tool setter who have not had previous experience with these pigmented celluloid, acetate, vulcanite, and casein materials, is somewhat nonplussed until he has become accustomed to the peculiar shape and form of tool, and the timing of the machine required, to get the desired results. But once the peculiarity of the materials and the manner of cutting it has been mastered, routine work follows as easily as when cutting metals and producing metal parts, and the vulcanite cap plugs come off the automatic machines all ready for grinding the ends in the special form grinding machine and then final polishing.

Compression Bars and Levers

The rolled gold and nickel from which these are made is supplied to the factory in strips, and the metal is passed through a series of power and hand presses, which are equipped with a full comple-

ment of form dies and punches from the blanking process to the last detail in bending, notching, and piercing. Altogether, it is a fine example in the art of metal stamping, and it demands a good deal of the knowledge and skill that is associated with that specialised trade. Tool making in this case is, of course, exceptionally fine and accurate not only as regards size and form, but also with respect to quality of finish. Each part must of necessity be free from burrs or flashes to conform to the high standard expected in this branch of industry, and all who are familiar with the work involved in keeping press tools in a high state of perfection to produce, and to continue reproducing large quantities of pressed metal parts, each and every one of which must be as near as possible a perfect specimen, will realise the amount of care and attention that must be given to these tools.

Practically all light industries have for many years past employed a fair amount of female labour, and fountain pen makers have not been slow to appreciate its value, not so much perhaps from the wage cost point of view, as from the quality of continuous production of light repetition work, for there can be no doubt that girls have the lightness of touch required for some branches of work. In stamping the metal parts mentioned above, each part passes through a number of operations before it is completed, and it has been found advantageous to use the fly press for a number of them, so that even after the tool maker has made the tools as near perfect as may be, something in the way of skill still remains for the press operator to exercise if the stamped part is to come up to expectation, and girls have been found to operate this type of machine quite satis factorily.

Making Gold Nibs

Notwithstanding the present high price of gold, all nibs made in this factory are of that metal. Some is supplied from Hatton Garden in strips, approximately 6in. wide, but Conway Stewart do much of their own metalling, and one floor of the building is entirely occupied in producing finished nibs from these strips of solid gold. The process is interesting and worth describing in some detail. A general view of this department is given on page 212.

In all there are about twenty-five operations needed to make a finished nib, but we can only deal with a few of the major operations. First, the strip is brought to a molten state in gas-heated crucibles, and is then run into moulds to give ingots of metal approximately 2in. by $\frac{5}{16}$in. by 6in. in size, which are afterwards cold rolled into strips and to a thickness of 0·020in. Nib blanks are stamped from these strips in small power-driven blanking presses, the blanks resembling a flattened truncated nib pointed with obtuse angles. At this stage the pointed ends of the blanks are tipped with a chip of Osmi-iridium, the hardest workable metal yet discovered. The real value of the tip is, of course, its wearing qualities. It is hard enough to scratch glass, and so adds to the life of the pen. At the same time it is workable, and can be ground through with the special circular 0·004in. thickness copper discs running in carborundum paste which are used for slitting the nibs. The melting point of Osmi-iridium is 3000 deg. Fah. It is therefore unaffected by being welded to the point of the nib. Gold will fuse at 1964 deg. Fah., so that the tip is welded to the nib by heating the gold to the fusing point while the chip of Osmi-iridium is held in position, and then allowing them to cool together. This welding operation requires care, but it is done very quickly and efficiently with the special but simple apparatus provided.

Following the tipping process, the blanks are rolled down to 0·015in. thickness and elongated accordingly, care being taken not to crush the iridium point, it remaining untouched until the grinding operation is reached. Then follows the form stamping in specially arranged power presses, name stamping, and piercing, and then slitting the point with the tip. The circular slitting disc is a fabricated tool composed of silk, rubber, and carburundum. It is 0·006in. thickness and runs at a very high speed, cutting through the tipped point to the proper depth in a very few seconds. Then follows the grinding and finishing the point on jewellers' buffs to all the various grades required.

Ink Feeder

Vulcanite ink feeders are ground to a good fit in the bore of the pen holder, and the tongue of the feeder is form ground from the stick. The ink and air grooves are milled with gang cutters on specially designed machines, having the cutter mandril supported under the table, and the cutter projecting through the table top, much in the same way as the cutters on a wood-workers' planing machine. The feeder is held in a holder and the operator passes it over the top of the cutter until the air and ink grooves are cut to the proper depth, the depth of the grooves being regulated by the height of the table.

Some of the pen holders are engraved on the outside of the barrel, and the designs of the engraving may be varied in many ways by finger adjustments provided on the machine. These hand engraving machines are shown on page 212. They are made by G. W. Heath and Co., and when set up are fully automatic in operation. A diamond is used in this engraving process, and very delicate marking is obtained. By manipulating the stops and actuating cams it is possible to produce intermittent engraving and thus leave a clear space for insertion of name or trade mark, which is either engraved or put on with a stamp under a press.

Immediately the parts are finished in the factory and have passed inspection, they are taken to the assembly room, where they quickly become a finished product. But to expedite assembly a pre-arranged plan is followed just as closely as are the operations in the factory, and to make this possible the first essential condition is to have every part, down to the last detail, ready to hand to go into its place as the unit is built up. This condition is just as necessary when applied to fountain pens as it is when applied to aero-engines or anything else that is made on a large scale. In this case the parts coming along in batches of one gross and on trays that ensure the full gross being there, much has been done to guard against delays that would arise if minor parts were missing.

Another direction in which rapid and accurate assembly has here been assisted is the perfectly fool-proof manner in which small, but all the same important, parts are arranged to be put together. Take, for instance, the hinging of the lever and its connection with the bar for compressing the rubber ink bag to exclude air previous to filling, and to release it to allow the ink to flow in. The whole arrangement is perfectly simple and is also perfectly mechanical; the hinge on which the lever swings when operated is formed and pierced for the hinge pin during the stamping process, and when it reaches the assembly room is all ready to be slipped in place and held there by the hinge pin. That would appear to be the normal way, but actually the hinge pin is put through the hinge first, and in thus reversing the order they have scored very neatly in providing a simple and quick method of hinging the lever without the least chance of it working loose. Actually, a split ring forms the lever hinge pin, the lever being threaded on the ring in the same way as a key is put on the ordinary split ring. The ring is then entered through the slot in the holder with the lever lying at right angles, and when the ring has been pressed home, it is turned with the lever through 90 deg., which brings the lever in line with the slot in the holder, and the ring slips into a circular groove which has been prepared for it in the bore of the holder, and that part of the assembly is finished, the whole operation taking about three seconds. The compression bar is flanged to receive the inner end of the lever, and since these two members are always in contact, the lever effectively prevents the bar from getting out of place.

That is just one instance of the thoroughness with which every operation and process has been thought out to simplify and improve the manufacture.

The tool room has only been mentioned casually, but every engineer will appreciate how busy and how important a section of the factory it is, tools being the deciding factor in all mechanical production, and the fountain pen is a good example of mechanical production from the time the raw material leaves the stores for the factory to the time the finished pen leaves the factory for its ultimate destination.

Locomotive Research and Development*

No. IV

(*Continued from page 182, August 18th*)

Railway Board Research (*continued*)

Nature of Tests.—For the first time in India apparatus having been devised, which was capable of giving quantitative results as regards flange forces, an intensive programme of testing was put in hand from the end of 1937 up to the time of our visit. These tests covered a wide range of variables in engine fittings and maintenance, and in track, and the following is a summary of the principal variations :—

(A) *Locality.*—By far the largest number of these test runs were made either between Arrah and Bihta, on the E.I.R. or between Bhusawal, and Nagpur, on the G.I.P.R., the latter containing sections of track on black cotton soil notably difficult to maintain. Individual runs were also made on certain portions of the M. and S.M.R., S.I.R., and N.W.R.

(B) *Engines :* (1) *Type.*—About 75 per cent. of the trials were made with "X B" engines, the remainder being divided between "X A," "X P," "H P S," and "X C" classes in that order of numbers.

(2) *Side Control Springs.*—On "X" class Pacifics coil springs varying from 15 cwt. to 31 cwt. initial loading were tried, as well as laminated springs with 15 cwt. to 90 cwt. initial loading.

(3) *Bogie Slides.*—Cast iron or bronze were tried with oil lubrication.

Five different friction materials of the Ferodo type were also employed on slides, lubricated and unlubricated.

An arrangement of needle roller bearings was fitted on the slides, to explore the effect of absence of friction at this point.

(4) *Hind Truck.*—The following variations were tried :—Cartazzi slides with different inclinations ; flat slides, cast iron on steel, lubricated ; flat slides, lined with two different friction materials of the Ferodo type, unlubricated ; pony truck.

(5) *Draught Gear.*—The Goodall type and the link type with and without German buffing gear were tried, also the Mestre type.

(6) *Condition.*—Engines were tried in different conditions of maintenance as regards axle-box side clearances, varying from new out of shops to very sloppy. Two E.I.R. "X B" engines, on which a large number of tests were made, were specially chosen to represent the extremes of maintenance in this respect. The side play in the boxes was as follows :—

	"X B 1920." Inches.	"X B 1921." Inches.
Bogie leading	0·4	0·2
,, trailing	0·4	0·2
Coupled leading	0·646	0·188
,, driving	0·246	0·188
,, trailing	0·879	0·188
Hind truck	0·8	0·125

(C) *Speeds.*—These trials were generally conducted at speeds of about 60 m.p.h., except when travelling over turnouts.

(D) Track.—E.I.R. ...	88½ lb. ...	B.H., D. and O. plate, and wooden sleepers	
G.I.P.R.	82 lb. ...	B.H.	C.I. pots
	100 lb. ...	B.H.	
M.S.M.R.	80 lb. ...	B.H.	C.I. pots
	90 lb. ...	B.H.	
S.I.R. ...	90 lb. ...	B.H.	C.I. pots
N.W.R.	90 lb. ...	F.F.	C.I. plates

(E) *General.*—Out of ninety-five high-speed runs, of which we were given detailed graphs and particulars, only sixteen were taken on curved track, the remainder being on the straight. In addition, a large number of tests were made on 1° in 12 turnouts at varying locations and speeds. On each run records were taken of bogie and hind truck displacements, and in some cases also of the bogie rotation in degrees. Flange forces were usually recorded at the same time for leading and trailing coupled wheels, but were not taken in all cases.

Results of Tests on Engines and Deductions Drawn by the Railway Board.—Amongst the numerous variables in operation, one fact stood out. As friction was introduced into the side controlling elements on bogie and track, so the amplitude of oscillation was reduced. Fig. 7 is a copy of a chart prepared by the Railway Board showing the relation between the two as established by numerous tests. Moreover, from a study of the recorded flange forces there appeared to be a definite tendency for coupled wheel flange force to vary with amplitude of bogie slide movement, at any rate on the straight. Fig. 8 shows

* Being Chapter VII of the Report of a Committee on "Pacific" Locomotives on Indian Railways. India Office. Price 6s. 9d. Some of the diagrams have been omitted owing to the impossibility of reduction.

points plotted from different trials with a trend line running through them.

These observed facts were supported by mathematical investigations based on theoretical work by Cain, Langer and Shamberger, and Carter; the Board's calculations showed that the critical speed of hunting increased with the coefficient of friction in the slides. Apart, however, from the foregoing, normal footplate observation also confirmed how hunting and undue oscillation disappeared when engines were fitted with friction damping on the slides fore and aft; the Railway Board, therefore, considered that they had justification for putting forward the recommendation that all "X" class Pacifics should be so dealt with, as a final cure for the trouble which had been experienced.

In addition to the above, which sets out briefly the major conclusion, certain other inferences which the Railway Board drew from these trials are of interest:

(*a*) That increasing the amount of initial side control successively up to 3¼ tons on an "X B" engine showed no reduction in oscillation or flange forces.

(*b*) That an increase in centring force on the bogie alone increased the amplitude of movement at the back end, if no alteration was made to the hind truck slides.

(*c*) That an engine with side clearances tight gives less oscillation than one with big side clearances; but that the flange forces with tight clearances on the coupled wheels may be higher than those with ample side clearances, should the engine

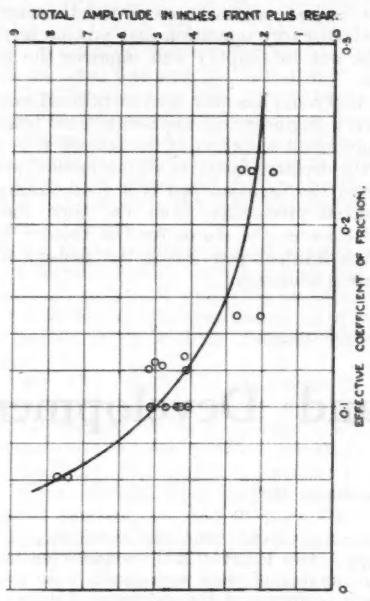


FIG. 7

be oscillating due to the combined effect of the bogie and hind truck clearances.

Comments on the Railway Board's Conclusions.—To some extent therefore on our arrival in India we were presented with a *fait accompli*. Research, theory, and ordinary observation appeared to indicate that the problem was solved. Instructions had already been issued by the Board for all "X" class "Pacifics" to be altered, and numbers of them had already been dealt with. On the other hand, the method of

Test No. and date.	Condition of engine.	Speed, m.p.h.	Track.	Maximum flange L coupled.	Forces T coupled.
				Tons.	Tons.
98 16/9/38	Needle rollers on bogie slides, Cartazzi hind truck. Goodall coupling	60	Straight	13	7·5
21 7/2/38	In original condition, *i.e.*, metal-to-metal bogie slides lubricated. Otherwise as above	62	Straight	6·5	6·0
65	Modified. Ferodo bogie slides, Flat truck slides with with Ferodo. German buffing gear	65	Straight	3·85	3·0
81 1/8/38	Same as 65 above	63	Curved, 2640ft. radius	14	4·0
Bogie control springs: Initial load, 25 cwt. Final load, 50 cwt.					

curing the trouble was at variance with the fundamental considerations which we have set out in Chapter III, and it was therefore necessary for us to make a very close study of all the records taken, in order to throw some further light on the problem.

Two considerations emerged. Amplitudes of oscillation had been regarded as a more important indication than flange forces, and the behaviour of the engine on straight track had been the main pre-occupation. There is perhaps some justification for the latter in that the Bihta derailment, and most of the others

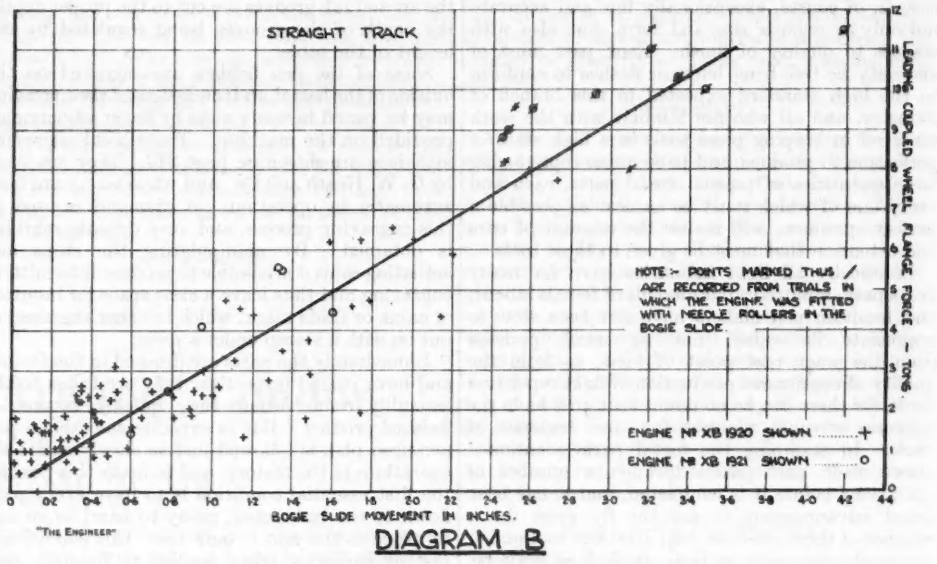

STRAIGHT TRACK
LEADING COUPLED WHEEL FLANGE FORCE — TONS.
NOTE:- POINTS MARKED THUS / ARE RECORDED FROM TRIALS IN WHICH THE ENGINE WAS FITTED WITH NEEDLE ROLLERS IN THE BOGIE SLIDE.
ENGINE Nº XB 1920 SHOWN .....+
ENGINE Nº XB 1921 SHOWN .....o
BOGIE SLIDE MOVEMENT IN INCHES.
"THE ENGINEER"
DIAGRAM B

FIG. 8

occurred on the straight. It is, however, the flange force alone which can damage and displace track, and any remedial measures taken on an engine must be equally effective on curved as on straight track.

Accordingly we concentrated on flange forces and on curved track. From an inspection of the records we found that whilst flange forces were reduced to small values on the straight by the Railway Board's modifications, on curves these forces remained equally as high for the modified engine as for the original engine on the straight. From the relatively small number of tests taken on curved track, it was possible to pick out examples confirming this. The table above, for instance, gives maximum flange forces recorded on "X B" No. 1920.

The flange forces recorded show that it is possible for a modified engine, exemplary in its behaviour on straight track, to exert flange forces on curves greater even than those exerted on the straight when the engine is deliberately fitted with special needle roll bearings in the slides, to obtain experimentally the worst hunting conditions.

In answer to objections that the dates of the above tests are too far apart to be comparable, and that test No. 81 on the curve was carried out at the height of the monsoon when the track was in its worst condition, we give a further table on similar lines, in which all the tests concerned were made within a week. The table below refers to "X B" No. 1921, which, as already stated, had tight clearances in its axle-boxes.

The above, taken from the Railway Board's test results, provides an indication that the use of high friction and low spring control values on bogies and

hind trucks is not a satisfactory solution of the problem in all its aspects. Further confirmation of our views is found in a diagram prepared by the Board on the same lines as Fig. 7. This shows flange forces on the leading coupled wheels in relation to bogie slide displacement on curves of 2640ft. radius, the progressive reduction in movement being due to the introduction of friction damping. Fig. 9 illustrates points obtained on various tests, and it will be noticed that the trend line, which we have added, indicates that there is little, if any, reduction in flange force as friction increases and the bogie slide movement in consequence decreases. It should be carefully noted that the conditions shown are very different from those for straight track in Fig. 7.

Test No. and date.	Condition of engine.	Speed, m.p.h.	Track.	Maximum flange L, coupled.	Forces T coupled.
				Tons.	Tons.
62 27/6/38	Needle rollers on bogie slides. Cartazzi hind truck. Goodall coupling	61	Straight	12	7·5
...	In original condition	No tests made with this engine as built			
55 22/6/38	Modified. Ferodo bogie slides. Flat truck slides with Ferodo. German buffing gear	62	Straight	6	5
58 25/6/38	Same as 55 above	68	Curved, 2640ft. radius	10	7·5
Bogie control springs: Initial load, 22·5 cwt. Final load, 50 cwt.					

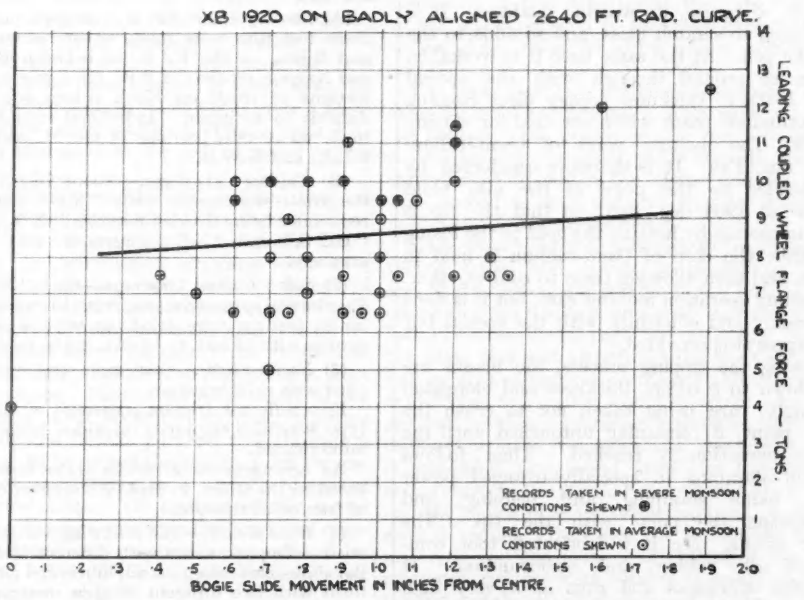

XB 1920 ON BADLY ALIGNED 2640 FT. RAD. CURVE.
LEADING COUPLED WHEEL FLANGE FORCE — TONS.
RECORDS TAKEN IN SEVERE MONSOON CONDITIONS SHEWN ⊕
RECORDS TAKEN IN AVERAGE MONSOON CONDITIONS SHEWN ⊙
BOGIE SLIDE MOVEMENT IN INCHES FROM CENTRE.
"THE ENGINEER"
RELATION BETWEEN FLANGE FORCE & BOGIE DISPLACEMENT ON CURVES.

FIG. 9

The effect of stronger bogie side control springs was

investigated by the Board, but records made with initial values rising from 1¼ to 3¼ tons gave no indication of any improvement in flange forces or displacements. An examination of the records in question, however, shows that :—

(*a*) Friction liners were fitted on the bogie slides, and the true effect of the control springs was masked.

(*b*) The Cartazzi slides were retained on the hind truck which had considerable side play, so that stiffening up the control at the front end was discounted by free movement at the rear.

(*c*) The tests were made on "X B" No. 1920, which had very large bogie and hind truck axle-box side clearances, about ½in. in the former and ¾in. in the latter. This gave a great deal of free movement, irrespective of the degree of control provided.

(*d*) The tests stopped short at an initial value of 3¼ tons for the bogie side control. More positive results might have been obtained from a higher value.

It is not surprising therefore that the Railway Board received no clear lead as to the value of increas- the initial side control on bogies. An opportunity might have been taken for ascertaining the effect of a bogie with metal-to-metal slides, with 3 tons initial side control and a pony truck at the back end, as in the tests with the experimental "X P" "Pacific" engine No. 3100' Displacements only were recorded and no flange force values were taken either on the straight or on curves.

Credit is due to the officers of the Railway Board for formulating a test programme covering so wide a field and for developing and perfecting the measuring apparatus for displacements and flange forces. The full diagrams taken on over 100 separate runs, which were placed at our disposal, have been of great value in our consideration of this matter, and if the calibration of the apparatus is correct we have no reason to doubt the reliability of the indications. The fact that the Board had, prior to our arrival, drawn differing conclusions from these tests results is due, as already mentioned, mainly to their concentration on the aspect of hunting which concerns straight track alone ; also to the fact that the choice and combination of variables on the engines tested were such as to prevent in many cases the emergence of clear and definite tendencies.

(To be continued)

Earth Leakage Protection for High-Frequency Furnaces

IN a coreless induction furnace a bath of molten steel is surrounded by a water-cooled inductor. The intervening space in a ¼-ton furnace is occupied by a refractory lining about 2in. thick, and in a 5-ton furnace by a lining about 5in. thick. With this range in furnace size the frequencies used lie between 2250 and 1000 cycles, whilst the furnace coils are supplied with current at pressures between 1000 and 3000 volts, giving rise to inter-turn potentials of 80 to 160 volts.

Unfortunately, failure of the refractory lining is not uncommon. Although many improvements have been made in lining materials since induction furnaces were introduced, the lining problem remains a serious one. Failure of the lining results in the molten steel coming into contact with the coil, with consequent damage to the copper conductors and possible explosion. When it first introduced its induction furnaces nearly eleven years ago, the Metropolitan-Vickers Electrical Company realised

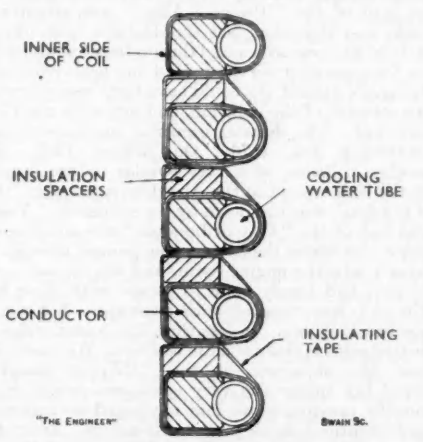


FIG. 1—SECTION OF FURNACE COIL

the possibility of such trouble occurring, and a coil was used with a conductor section as shown in Fig. 1. Apart from having advantageous electrical properties over a plain tubular conductor, the section ensured that a thick wall of copper existed between the cooling water and steel, thus reducing the danger of an explosion. When molten steel comes into contact with the inductor coil, the extent of the damage depends largely upon whether the coil is energised or not. If the coil is not energised the steel solidifies very rapidly and little, if any, can find its way between turns to the outside. Apart from burning the insulation, which is easily renewed, little is done to the copper. But if the coil is energised an arc is struck which, if maintained, burns through the copper until the water circuit is punctured. Hence it is obvious that any arrangement which will make the circuit dead directly or preferably before contact is made between the furnace coil and charge is valuable. Apparatus for this purpose is described by Mr. P. G. H. Burbridge in the August issue of the *Metropolitan-Vickers Gazette*.

The most obvious way in which an auxiliary circuit can be made is to connect a relay between the high-frequency circuit and earth, and then earth the charge. Such a circuit would be completed by contact between the coil and the charge, or between any part of the high-frequency circuit and earth. An electrode buried in the bottom of the furnace lining is sufficient to earth the charge. When hot the lining material becomes a conductor. With the electrode separated from the charge by a thin layer of lining, the resistance will be but a few ohms, and this resistance is of no importance. The high-frequency system is connected to earth by the special circuit shown in Fig. 2, and operates by injecting a 50-cycle supply into the high-frequency system. The magnitude of the 50-cycle current depends upon the resistance between the high-frequency system and earth, and a relay is arranged to trip the main high-frequency contactor, thus isolating the high-frequency generator should the current rise above a certain value.

From Fig. 2 it will be seen that the relay circuit, which, incidentally, is patented, comprises a small single-phase transformer tapped on the primary side and supplying a relay through a resistance *a*, *b*, *c*. Across the resistance *b*, *c*, and the relay is connected the primary of a high-impedance, step-up coupling transformer with a by-pass condenser con-

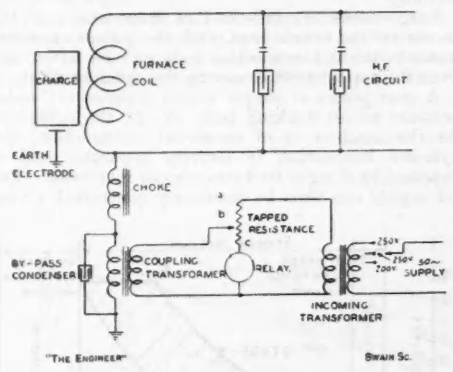


FIG. 2—DIAGRAM OF EARTH LEAKAGE PROTECTION

nected across the secondary. One end of the transformer's secondary is connected to earth, and the other to the high-frequency circuit *viâ* a high-frequency choke. The relay is fitted with two sets of contacts, one of which is connected in the tripping circuit of the generator contactor and the other in a lamp circuit to indicate when the relay has tripped.

The resistance *a*-*b* carries the relay and coupling transformer currents, and provided that the latter remain small, the relay remains energised. But as the transformer current increases the potential drop along resistance *a*-*b* increases until a point is reached at which the relay is de-energised. With the insulation resistance between earth and all parts of the high-frequency circuit infinitely high, no current other than the magnetising current will flow in the coupling transformer, and by turning the transformer with the by-pass condenser this current can be reduced to minimum.

Any fault with finite resistance between earth and the high-frequency system, including a fault between the furnace coil and the charge within it, will allow 50-cycle current to flow from the coupling transformer through the high-frequency choke and the fault and back *viâ* the earth connection. This results in additional current through, and a fall of potential along the resistance *a*-*b* with a consequent reduction in the current through the relay. The maximum current through the relay is in the neighbourhood of 55 milliamperes. A fault resistance of about 3500 ohms will reduce the relay current to 32 milliamperes, at which point the relay becomes de-energised. With a fault of zero ohms, the relay current will drop to 10 or 12 milliamperes. From this it will be seen that a few ohms resistance between the furnace earth electrode and the charge will be of little detriment.

Moreover, if the 50-cycle supply to the relay circuit should fail, the relay will trip, thus ensuring that the furnace cannot be operated unless the relay circuit is in operation. On the position in the high-frequency circuit at which a fault occurs the voltage across the fault depends. The fault current which is governed by this potential must pass through the high-frequency choke, which limits it, and any arc

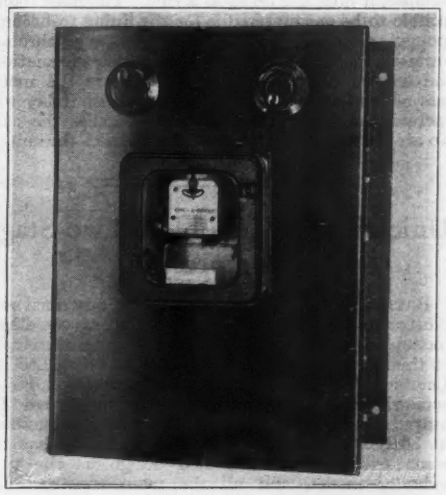


FIG. 3—EARTH LEAKAGE PROTECTION PANEL

which may be struck. The condenser by-passes the fault current round the coupling transformer and the value of the condenser is selected to ensure that there is no danger of sufficient high-frequency current being injected into the relay to keep it energised.

In Figs. 3 and 4 are shown front and rear views of an earth leakage protection panel. The by-pass condenser is to be seen at the top left-hand corner of Fig. 4, and the incoming supply transformer below it. On the right is the coupling transformer and below it the high-frequency choke. The resistances *a*, *b*, are in the form of toroidal-wound variable units to be seen at the top of the panel. They enable sensitivity adjustments to be made to suit site conditions, and to prevent accidental movement the resistances may be locked in the selected positions by the small knobs offset on the resistance control knobs to be seen in Fig. 3.

When a new lining is sintered into a furnace water is set free and reduces the water-cooled inductor insulation to earth. In large furnaces, the resistance may be reduced to a value well below the sensitivity

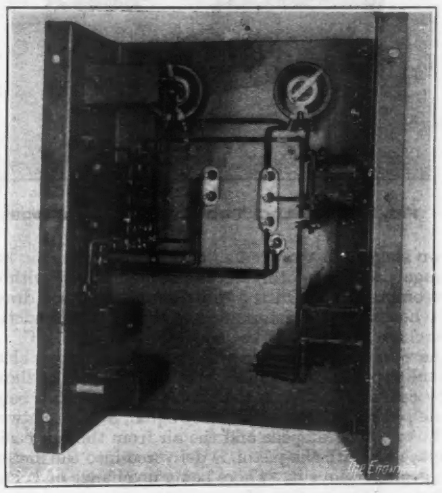


FIG. 4—REAR VIEW OF PANEL

of the earth leakage circuit, resulting in premature operation of the relay. Since the furnace has to be worked under these conditions, the relay circuit can be desensitised by connecting a resistance between earth and the earth lead of the protective circuit in place of the direct earth connection as shown in Fig. 2. By bridging this resistance with a switch, the circuit can be used in either the normal or desensitised condition at will, and a second contact on the switch is provided to give indication of the desensitised condition. If the relay circuit is set to trip normally at, say, 3500 ohms, and a desensitising resistance of 2500 ohms be switched in, it can trip only if the insulation falls to 1000 ohms or below. As it is important that the relay circuit should be

normally used at full sensitivity the electrician in charge of the plant alone should be permitted to operate the desensitising switch.

The 50-cycle current flowing through the relay is indicative of the state of the insulation of the high-frequency circuit. With good insulation and a sound lining within the furnace, this current will be at a maximum, but if minor faults develop it will diminish.

On a large plant a milliameter is sometimes connected in series with the relay and is mounted on the furnace control panel. Warning of a slowly developing fault is thus given to the operators, and according to the value of the current flowing after a fault has caused the relay to trip, the severity of the fault may be judged.

Whilst a faulty furnace lining may occasionally collapse, it does not do so as a rule. The most likely trouble to be encountered is for the lining to become spongy, allowing metal to trickle slowly through towards the coil in fine capillary-like formation, and several melts may be made before the metal gets near to the coil. But, as shown, the relay will operate before the metal actually reaches the coil. No arc is struck and no damage is done to the coil.

Unicylinder Monobloc Two-Stage Compressor

Rather more than a year ago we described and illustrated an interesting two-cylinder, two-stage, monobloc compressor, at that time being introduced to the market by J. Browett-Lindley (1931), Ltd., of Letchworth. The company has now developed a somewhat smaller compressor to meet the demand for outputs ranging from 150 to 250 cubic feet per minute at 80/150 lb. per square inch pressure. It has the same patented self-contained design as the two-cylinder model, and all the main constructional features of the large Browett-Lindley compressors.

Unlike other single-cylinder, two-stage compressors, however, this machine has a single piston of one diameter only, the first stage compression taking place beneath the piston and the second stage above. This construction is claimed to offer several advantages over the normal "stepped" piston type, both from the manufacturing and maintenance points of view. The design of the machine is shown in the engravings, Figs. 1 and 2.

A glance at the diagram, Fig. 3, will show the ingenious way in which the clearance volumes of the

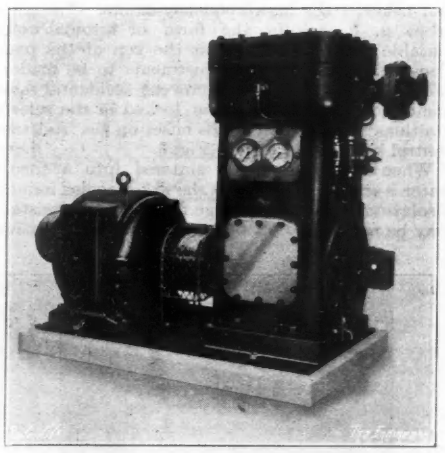


Fig. 1—Monobloc Two-Stage Compressor

two stages are arranged so that the air from the first stage passes smoothly to the second stage, without recompression. On the downward stroke air drawn in beneath the piston during the previous suction stroke is compressed, as shown by the curve B C. At the same time air from the large second stage clearance expands in the space above the piston, as shown by curve F C. When the pressures above and below the piston becomes practically equal, a valve between the two spaces opens and the air from the decreasing space beneath the piston is delivered into the increasing space above it. There being no change of volume during this process, the pressure remains constant, and line C D represents delivery from the first stage and suction into the second stage. On the following upward stroke of the piston, the air in the second stage is delivered in a normal manner, and suction in the first stage also occurs normally. The volumetric efficiency, the firm states, is as high with this construction as with the normal two-cylinder type. The overall volumetric efficiency, in fact, depends, as will be inferred from the diagram, Fig. 3, only upon the clearance space in the first stage, which has been made as small as is practically possible.

The clearance space of the second stage portion of the cylinder is larger than usual, and advantage is taken of this fact to incorporate a ribbed cooler inside the cylinder. It acts as an auxiliary intercooler, and there is, moreover, a further cooling effect, owing to the mixing of the air from the first stage with the cool air already present in the second stage clearance space. Hence, the whole compression cycle is claimed to approach more nearly the theoretical ideal than it does in any other two-stage machine on the market. The outlet air from the machine is said to be exceptionally cool.

The compact totally enclosed construction may be seen from the photograph, reproduced in Fig. 1. All working parts, including fly-wheel, intercooler, air control governor, &c., are contained in the box-shaped housing. The intercooler, built into the cylinder block, is so arranged that it is easily accessible for cleaning. It is of the water-cooled finned-tube type, and has been shown to be as effective on test

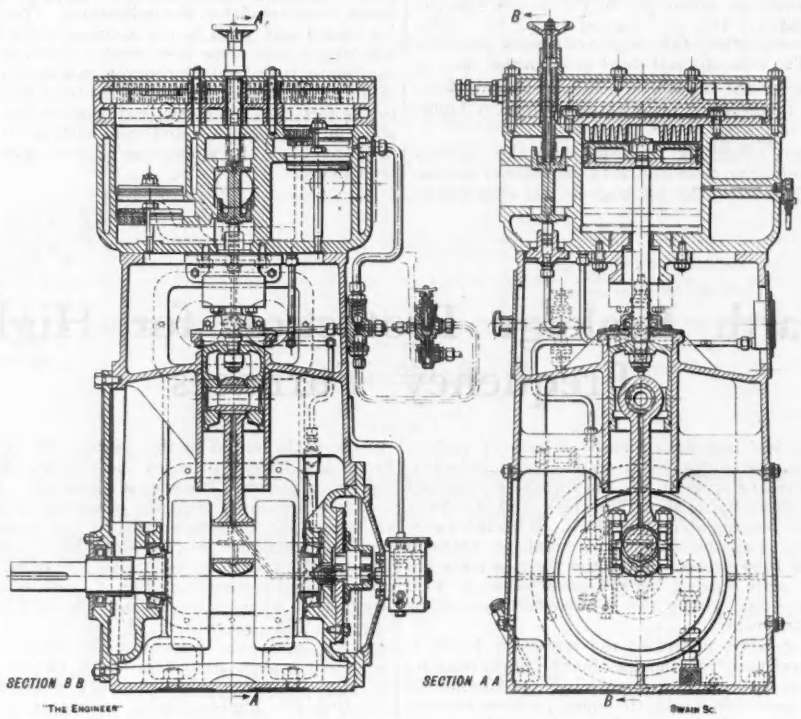


Fig. 2—Sections Through Compressor

as the standard vertical intercoolers which are usually supplied with two-stage compressors as separate units. Valves are of the automatic plate type. Chambers and covers are water cooled, a feature which increases efficiency and prevents overheating.

Large doors are provided at front and rear for access to the crank case, and the valves, pistons, piston-rods, and connecting-rods can be lifted out from the top without removing the cylinder block.

A gear pump of simple design supplies oil under pressure to all working parts except the cylinders. As the machine is of crosshead construction, the cylinder lubrication is entirely separate, and is supplied by a sight-feed mechanical lubricator. The oil supply can thus be accurately controlled, giving

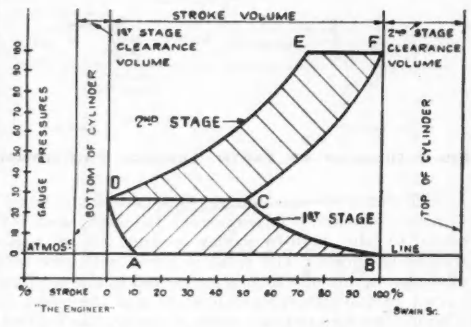


Fig. 3—Cycle Diagram

clean air and preventing waste of oil and carbonisation of valves and control gear. An automatic inlet relay governor is provided, whereby the outlet pressure can be maintained at any predetermined value. In addition, the high-pressure portion of the cylinder is automatically unloaded during periods of light load.

Sixty Years Ago

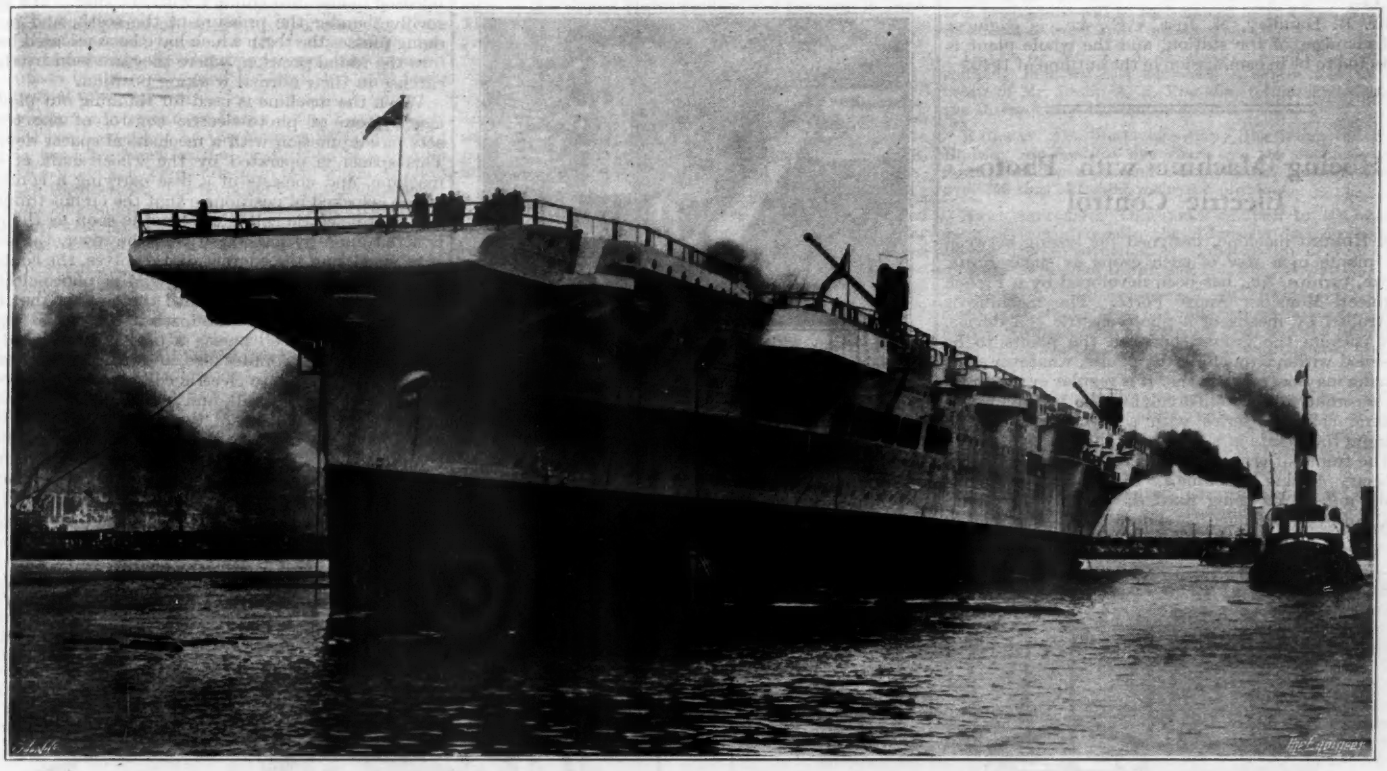
Pleasure Steamer Collisions

When the Thames steamer "Princess Alice" was run down and sunk off Barking by the screw ship "Bywell Castle," with the loss of many hundreds of lives, we had much to say that was not complimentary concerning those who designed and built her, those who subsequently modified her structure for the requirements of excursion traffic, and those, at the Board of Trade, who passed her as fit for her intended work. The impact of the collision was slight; yet it was sufficient to tear a hole in the side of the steamer, and thereby to allow water to flood the central, engine-room, compartment. She was thus deprived of the buoyancy of the middle portion of her length. The two ends remained afloat, but the structural strength of the central section was insufficient to sustain the load thrown upon it. Before the steamer could be beached or reach shallow water under the drift of the current, her back broke, and the two ends rose out of the water. We maintained at the time that there was no technical reason why river steamers should not be made sufficiently strong amidships to prevent such a mishap if their engine-rooms became flooded. We further maintained that the hull of the "Princess Alice" was structurally weak, and that that fact should have been obvious to those who owned her and those officials who certified her for passenger service. Had she been reasonably strong, we argued, she could have been beached within five minutes of the collision, and not a life need have been lost. The disaster occurred on the evening of September 3rd, 1878. On August 13th, 1879, another collision of a very similar nature occurred on the Thames, when the Aberdeen screw ship "City of London" was run down by the steamship "Vesta." The hull of the "City of London" was cut down far below the water line, the water poured through the breach into the engine-room, and the engineers and firemen had barely time to escape with their lives. The ship was crowded with passengers, but she did not break in two. In less than five minutes she had drifted ashore, and not a life was lost. We maintained that the stoutness of the "City of London" saved her under the very conditions which eleven months previously we had envisaged as calling for such stoutness in all pleasure steamers. Apart from the gratifying absence of loss of life, we called attention to the fact that any extra cost or reduced carrying capacity involved in making a ship reasonably strong was likely to be more than regained when it came to the salvage of the ship after a collision. The wreckage of the "Princess Alice" was still being fished up from the Thames bed eleven months after the disaster. Within forty-eight hours of the mishap to the "City of London," she was afloat again and a day or so later she was in dock for repairs.

High Duty Alloys, Ltd.—At the new Redditch works of High Duty Alloys, Ltd., on Wednesday, August 16th last, Sir Kingsley Wood inaugurated what is stated to be the largest drop hammer in the world. This hammer, built in the United States by the Erie Foundry Company, has a total weight of 455 tons, the reciprocating weight being 29 tons. Its foundation consists of about 1800 tons of concrete into which the sub-anvil extends some 14ft. and rests upon oak timbers. It has a height of 27ft. above floor level, and the cylinder is 39in. diameter with a stroke of 72in. The hammer, which has been installed in keeping with the company's system of installing equipment ahead of production requirements, will be used in the making of the larger alloy aero-engine parts, which are rapidly increasing in size. When completed the new works will cover an area of more than 20 acres, and the stamp shops which have been built are already in full production.

H. M. AIRCRAFT CARRIER "FORMIDABLE"

HARLAND AND WOLFF LTD., BELFAST, BUILDERS



H.M. Aircraft Carrier "Formidable"

As recorded elsewhere in to-day's issue, the new aircraft carrier H.M.S. "Formidable," the latest addition to Britain's Naval Air Arm, was launched on Thursday, August 17th, from the shipyard of Harland and Wolff, Ltd., at Belfast. There was a large assembly of guests, including members of the Board of Admiralty and Admiralty officials, as well as members of the Government of Northern Ireland and the leading men of Belfast. The christening ceremony was performed by Lady Wood, the wife of Sir Kingsley Wood, the Secretary of State for Air. The vessel left her launching ways at twelve noon unexpectedly, about half an hour before the time scheduled, and safely took the water, being brought round to the fitting-out wharf by the attendant tugs. The new aircraft carrier is a further ship of the "Illustrious" class, of which four other ships are under construction on the Tyne, Clyde, and Barrow-in-Furness. In type the "Formidable" is generally similar to the "Ark Royal," which was fully described by Sir Stanley Goodall, Director of Naval Construction, at the spring meetings of the Institution of Naval Architects, as reported in our issue of March 31st, 1939. The length between perpendiculars is 685ft., with a length of flight deck of 800ft. The water line length is 721ft. 6in. and the breadth at the water line is 94ft. 9in. The ship has a standard displacement of 22,000 tons with a mean draught of 22ft. 10in. Three-shaft propelling machinery of the Parsons single-reduction geared type, with a total output of over 100,000 S.H.P., is to be installed, taking steam from high-pressure Admiralty Yarrow small-tube type boilers. A speed of over 30 knots is anticipated. The armament comprises sixteen 4·5in. guns, designed for high-angle and low-angle fire, four pompoms, twenty anti-aircraft machine guns, and four saluting guns. The new ship is due for completion in 1940.

Extensions at Portsmouth Electricity Works

INCREASING loads have made it essential to extend the Gunwharf Road Power Station at Portsmouth Electricity Works, and accordingly contracts have now been placed with Bennis Combustion, Ltd., for two water-tube boilers (£189,848), British Thomson-Houston Company, Ltd., 30,000-kW turbo-alternator (£109,684), Johnson and Phillips, Ltd., cables (£6222), and Mather and Platt, Ltd., fire protection equipment (£1261).

The general lay-out is shown in the illustration, where 14 and 15 show the position of the new boilers.

The new boiler plant will comprise two Bennis "Quadrum" water-tube boilers, each rated for a normal continuous evaporation of 150,000 lb. per hour, with steam at the superheater outlet at 625 lb. per square inch and 850 deg. Fah. (controlled), with feed temperature at the economiser inlet 320 deg. Fah. They will be built face to face with a firing aisle between, and each boiler will be provided with a steel chimney supported by the fan floor beams. The chimneys are to be of self-supporting type of steel plate construction, rising to a height of at least 200ft. from ground level and lined throughout with Gunite. The building will be steel-framed and sheeted. Travelling grate mechanical stokers of the Bennis patent unit carrier bar type, suitable for operation with induced and forced draught of preheated air, are to be employed.

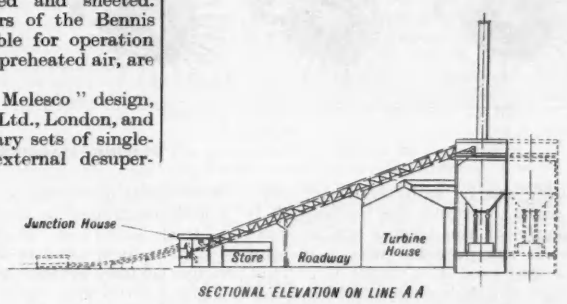
The superheaters will be of the "Melesco" design, made by the Superheater Company, Ltd., London, and will consist of primary and secondary sets of single-pass detachable elements, with external desuperheaters placed in circuit between them. The steam connections and butterfly valves will be so arranged that a varying quantity of steam can be desuperheated before entering the secondary superheater, thus controlling the final temperature from a thermostat placed in the outlet to the steam main. The steam output and combustion will be controlled automatically according to demand by a Kent electrical system, and it is intended to extend this system to certain of the existing boilers.

The steel tube economisers will be supplied by E. Green and Son, Ltd., and James Howden and Co., Ltd., will supply rotary generating air preheaters and forced and induced draught fans with vane control.

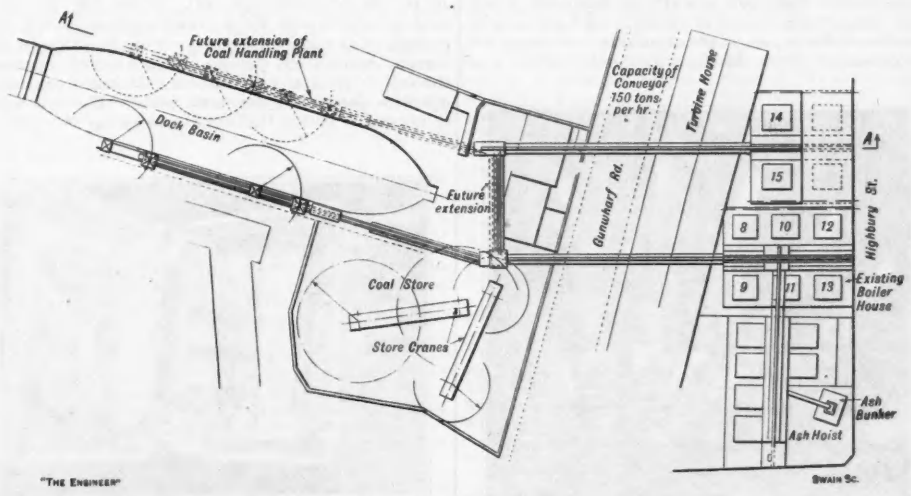
The coal-handling plant will comprise two belt conveyors, junction houses, gantries, and a bridge over Gunwharf Road. Each conveyor will be capable of handling 150 tons per hour of small coal, averaging 40 cubic feet per ton, when operating at 300ft. per minute.

The ash-handling plant is to comprise drag link submerged ash conveyors for collecting from each unit and delivering on to the extension of the existing main belt conveyor.

The steel work in foundations, grillages, &c., pressure piles and complete boiler-house, with goods and passenger lift are included in the boiler plant contract. The design of the structures is to harmonise with the existing station, and this portion of the contract has been sublet to Peirson and Co., Ltd.,



SECTIONAL ELEVATION ON LINE A A



PLAN OF GUNWHARF ROAD POWER STATION, PORTSMOUTH

London, who carried out similar work in the existing station.

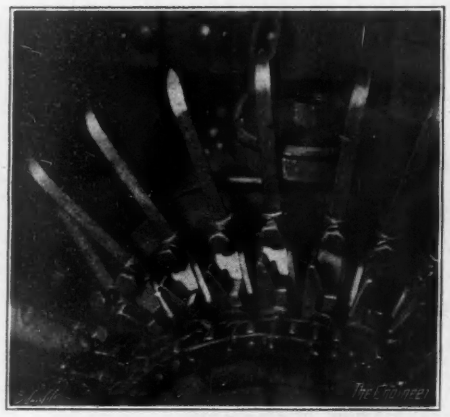
The coal bunker, of mild steel plate and similar in design to the existing bunkers, is to be lined throughout on the inside with granolithic, reinforced with Expamet, and secured to the plating with spot welding.

Mr. B. Handley, M. Inst. C.E., &c., is engineer and manager of the station, and the whole plant is expected to be in commission in the autumn of 1940.

Hoeing Machine with Photo-Electric Control

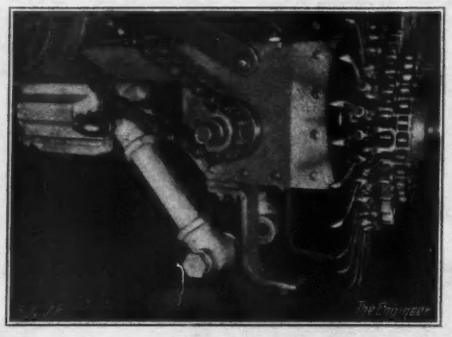
A Hoeing machine, designed for hoeing between the plants in a row of such crops as sugar beets, maize, turnips, &c., has been developed by a French engineer, Monsieur André Ferté. The machine is controlled by means of a photo-electric cell device, and permits the ground between the plants to be loosened without touching the plants, whatever their spacing may be, and whether it is regular or irregular. An alternative control, involving the use of photo-electric cells, in series with a mechanical spacer, permits the plants in a row to be thinned out.

The frame of the machine is similar to that of an ordinary hoeing machine. The revolving hoeing tools, instead of being fixed directly to the frame, are, however, arranged to slide along a bar, so that their spacing can be adjusted as necessary. Moreover, in order to permit the machine to be guided independently of the tractor which draws it, the front wheels are provided with a steering system similar to that used in a motor car. This arrangement permits the tools always to be kept on the rows being hoed. The tools are driven from the wheel shaft of the machine, and as a result each hoeing tooth loosens a definite part of the ground in relation to the advancement of the machine and independently of its speed. A chain and sprocket drive from the rear wheel shaft transmits power to a long shaft, on which a set of sprockets and driving chains for each of the hoeing tools is provided. These sprockets are connected to bevel gearing enclosed in cases which operate the actual tool shafts.

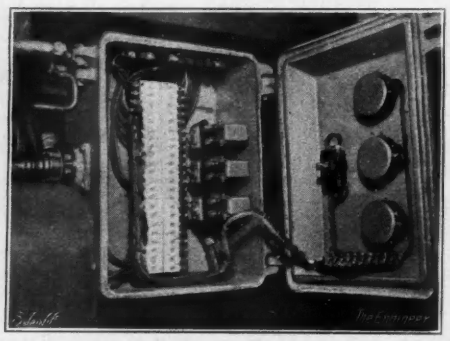


Hoeing Disc

Each of the tools consists of a disc from which a series of thirty radial teeth, about 4in. or more in length, projects. Normally, as the disc turns, the teeth dig into the ground, each one loosening about ¾in. of ground. Each of the teeth is, however, hinged, and is designed in such a way that the teeth would all be drawn into a position parallel with the axis of the disc—that is, in a position in which they would not touch the ground—if it were not for a series of catches. One of these catches is provided for each tooth, and hooks over a projection on the rear of the base of the tooth, holding it firmly in the radial position. Each of these catches is controlled by an electro-magnet, operated by a relay placed in an instrument cabinet installed on the frame of the machine alongside the seat. This relay is, in turn, controlled by another relay operated by the photo-electric cell. The photo-electric cell is mounted on one branch of a tube formed in a U and fixed immediately in front of the hoeing tool. The other branch of the tube carries a small electric lamp which shines on to the photo-electric cell. When the beam of light is interrupted by a growing plant during the passage of the machine along a row, the drop in the current carried by the photo-electric cell operates the cell relay in the instrument case, which, in turn, operates the electro-magnetic relay. The cell relay is normally under the same tension as the photo-electric cell, while the electro-magnetic relay is normally under no tension. When the cell relay operates, it closes the contact of the electro-magnetic relay, thereby exciting the magnet corresponding to the tooth which is about to penetrate the ground, and draws back the catch holding it. The spring acting on the tooth in question draws it into the horizontal position and prevents its penetrating the ground. The number of teeth thus released depends on the size of the plant which causes the action. The longer the light beam is interrupted, the more teeth will be released.



Drive to Hoeing Disc and Light Tube

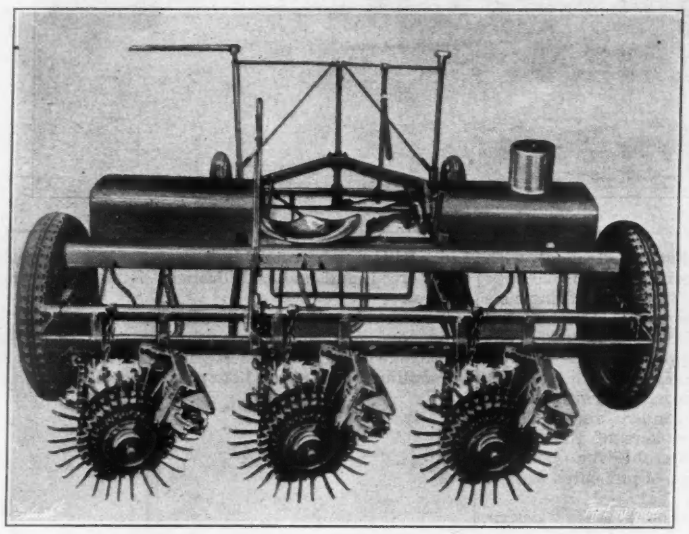


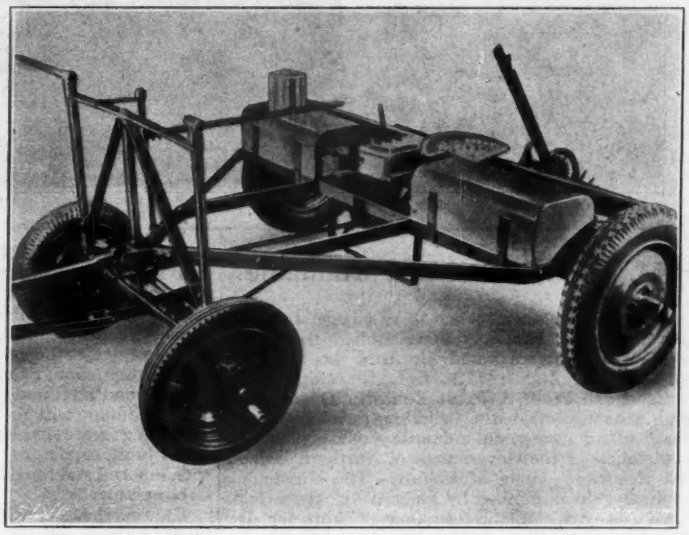
Relay Cabinet

At the top of each hoeing tool is a disc in a plan at right angles to that of the tool disc. This disc is mounted on a vertical pivot, and its position is such that as the tool disc turns, the teeth which have been released, come into contact with the disc. The disc revolves under the pressure of the teeth, and in so doing presses the teeth which have been released back into the radial position, where they are held by their catches in their normal working position.

When the machine is used for thinning out plants, this system of photo-electric control of the teeth acts in conjunction with a mechanical spacer device. This spacer is operated by the wheel shaft of the machine, and consists of a disc carrying a contact, which is locked in position so that the circuit through the photo-electric cell is closed. As soon as the cell is acted upon by passing a plant, however, this lock is released, and the contact disc revolves, the contact being maintained open—that is, the photo-electric cell is cut out of circuit—until the contact disc has made a complete revolution, when the disc is again locked until the cell passes a plant. The speed of revolution of the contact disc, and hence the distance over which the photo-electric cell control is cut out, can be regulated at will, and independently for each of the three tool discs of the machine. When this system is in use the first plant passed by the machine is untouched. At the same time the photo-electric cell control is cut out, so that the following plants are hoed up over the distance for which the machine is set. Thereafter, the photo-electric cell being again in circuit, the first plant which is encountered is spared, the following plants being again hoed up over a certain distance, and so on. As a result, the plants are thinned to a desired minimum spacing. The actual spacing between any two plants may be greater than this minimum, since the machine allows the first plant encountered after the minimum to remain, but it can never drop below the minimum.

The relays required for the operation of the machine are, as previously stated, enclosed in weatherproof cases at the sides of the driver's seat. Projecting from one of these cases is a rubber-covered weatherproof flexible cable, which is run from the case to the magneto of the tractor used to draw the machine. If the tractor has no magneto, the current can be produced by a small independent petrol motor generator mounted on the frame of the hoeing machine itself. The machine is stated to be capable of hoeing about 8 acres of plants per day, regardless of their spacing. It requires only one operator and a tractor. Accompanying engravings illustrate the machine.





Hoeing Machine with Photo-Electric Control

Coastal Shipping.—At most of the principal ports in this country coastal shipping shows signs of a general recovery. According to recently issued returns by the Board of Trade during the seven months ended July 31st, the net tonnage of coastal ships arriving and departing with cargoes was 34,407,277 compared with 33,349,628 tons in the first seven months of 1938.

Another Big American Dam.—The first step in the construction of the Ross dam, on the Skagit River, in the United States, has been completed. This dam is being built in three steps; the first, just completed, carries it to a height of 227ft. as a variable-radius arch structure; the second step will heighten it by a further 215ft., and the third step will enlarge it to a heavy gravity structure, arched in plan, and with a total height of 655ft. The dam, when completely finished, will create a 3 million acre-feet reservoir to give storage for power use and flood control. The first part of the scheme has cost about 5½ million dollars, and the next step will cost nearly another 5 million dollars. The completed part of the dam has vertical and horizontal keys constructed on its downstream face and a system of horizontal depressions on the top surface to enable consolidation to be effected with the intermediate and ultimate structures.

Rail and Road

MOTOR VEHICLE SALES.—The total sales of motor vehicles of all classes in this country for the nine months ended June show an increase of nearly 7 per cent. over the corresponding period of last year. The sales of private cars alone increased by over 9 per cent; 13,000 more private cars were produced during the nine months ended June than in the same period last year, but 3600 fewer commercial vehicles.

PROPOSED NEW ROAD IN ESSEX.—The Essex County Council has been asked by the Ministry of Transport to put in hand a scheme for the construction of a by-pass for the London and Yarmouth main road where it passes through Ingatestone. The proposed by-pass will be about 1¾ miles long and include dual carriageways, cycle tracks, and footpaths. It will be completed in about a year, and a tender valued at £96,676 has been accepted.

AN UNUSUAL ELECTRIC MOTOR COACH.—A note in the Electric Railway Traction Supplement of the *Railway Gazette* says that the French National Railways have introduced in the Bordeaux area a motor coach which can work either directly off the 1500-volt D.C. overhead contact wire or on non-electrified lines through a diesel engine and generator. It is being used at the moment between Bordeaux and Périgueux, a route which is electrified only between Bordeaux and Coutras, a distance of 32 miles.

ROAD KERB MARKING.—Satisfactory results have been obtained from the use in France of concrete kerbs (either precast or cast in place) containing a white porcelain inlay. Experiments carried out with vehicle headlights on an otherwise unlighted road showed that this type of kerb was visible at a distance of more than 330ft., a clear contrast with the actual road surfacing being observed. The porcelain inlay, which is non-porous and not effected by extremes of temperature, retains its brightness indefinitely.

TRAFFIC LIGHT SIGNALS.—The Minister of Transport has decided, after consultation with the Commissioner of Police and subject to the concurrence of the highway authorities concerned, to discontinue for an experimental period, at certain selected traffic light installations in London and other large cities, the use of the red-amber signal as an intermediate phase between the red and green. The purpose of the experiment, which will probably continue for some months, is to ascertain whether there would be any advantage in dispensing with the red-amber period.

WOOD LANE STATION.—The London Passenger Transport Board has placed a contract for the demolition of Wood Lane Underground Station. A new station is to be built some 300 yards away. The tracks forming the loop round which westbound trains end their journey and are brought back to the eastbound line is to be abandoned, as are the existing platforms at Wood Lane. Two island platforms with three tracks will be built at the new station, and through trains will use the outside tracks. Trains ending their journey will use the single track between the platforms, and reverse into the new siding to be built west of the station.

TRUNK ROAD IMPROVEMENT IN SUTHERLAND.—The Minister of Transport has accepted the tender of John McAdam and Sons, Ltd., of Aberdeen, in a sum of over £59,344 for an improvement of 8¼ miles of the London, Edinburgh, and Thurso trunk road in Sutherland, between the Mound railway level crossing and Clashmore and Spinning dale. The present carriageway has an average width of about 15ft., and the surface is in poor condition. The road will be widened to an average width of 30ft., with an 18ft. carriageway surfaced with bituminous macadam. The alignment will be improved by the construction of short diversions where necessary.

NEW BRIDGE OVER THE RIVER ALLAN.—Work will shortly begin on an important improvement to the Great North Road at Bridge of Allan, Stirlingshire, where the bridge over the River Allan is to be replaced by a new one with improved approaches at an estimated cost of £63,000. The new bridge, necessitated by the narrowness of the old one and the sharp bends at each end, will be 64ft. wide, and the lay-out will consist of two 20ft. carriageways, separated by a central reservation, and two 9ft. footpaths. To straighten the present unsatisfactory alignment, the bridge will cross the river obliquely with a clear span of 144ft., and the new sections of road will bring the length of the improvement up to nearly ¼ mile.

CREWE STATION SIGNAL-BOX IMPROVEMENTS.—The famous signal-boxes at Crewe North and South Junctions are to be rebuilt shortly by the London, Midland and Scottish Railway Company. Both boxes, which stand at heights of 28ft. and 22ft. above rail level respectively, will be resited in suitable positions and will be considerably reduced in size. When the reconstruction is complete, the existing electrically operated semaphore signals will be replaced by the colour light type, which, supplemented by route indicators (including the new standard junction type) will enable 274 signal arms each electrically lit at night to be reduced to 72 colour light units, and will at the same time improve visibility to drivers. The junction indicators, which will be similar to those recently installed at Rugby, are complementary to colour light signalling and form a method of advising drivers at long range of the route which the train is to take, one signal indication being used in conjunction with a route indication, up to a maximum of six diverging routes ahead. No fewer than 500 passenger trains, carrying a quarter of a million passengers, use Crewe Station on a busy summer Saturday, involving the use of 266 levers in the North Junction box and 247 in the South Junction box. In addition to trains, the boxes regulate 250 movements a day of locomotives passing to and from Crewe North and South engine sheds. The overall extent of the new signalling covers 3¼ miles of the main line, all running lines being protected by continuous track circuiting for a distance of approximately 1 mile north and 1 mile south of the station, whilst the number of working levers will be considerably reduced in the new arrangement. The whole of the signalling alterations and reconstruction work is being carried out by the L.M.S. staff, with the minimum of interference with the daily operations at this busy centre.

Miscellanea

UNEMPLOYMENT IN AMERICA.—Returns issued by the National Industrial Conference Board show that unemployment in the United States declined 4·3 per cent. in June. The number of unemployed at the end of that month is given as 9,552,000, and it was estimated that 54,580,000 people were at work.

REOPENING A DERBYSHIRE LEAD MINE.—Production was stopped at the Ladywash lead mine, near Eyam, about twenty years ago, and steps are now being taken to reopen the workings. Plant has been installed to pump out the water which has accumulated in the workings, the shaft of which is 860ft. deep.

CRUDE OIL PRODUCTION.—During the first six months of this year the world production of crude oil totalled 1010 million barrels, the highest ever recorded for a similar period. Of this total, over 616 million barrels, or 61 per cent., was produced in the United States. South American countries, including Trinidad, produced 154 million barrels, European countries over 135 million barrels, and Asia over 98 million barrels.

WILLIAM MURDOCH.—This year marks the centenary of the death of William Murdoch, and the William Murdoch Memorial Committee has entrusted Mr. Bernard Drummond with the task of preparing a life of him. Mr. Drummond, whose address is 1, Grosvenor Place, London, S.W.1, is asking for the loan of any documents concerning the early history of gas or for suggestions with regard to sources of information on Murdoch's work in this and other fields.

DISPOSAL OF BRINE FROM AMERICAN OIL WELLS.—In a paper before the American Geophysical Union, Mr. D. G. Thompson said that the disposal of brine from oil fields in a way not to contaminate fresh ground waters or surface waters would require a capital investment of at least 100 million dollars. The ultimate cost would possibly be double this figure and annual operating costs might be as much as 18 to 33 per cent. of the capital investment.

THE GAS GRID.—Production has begun at the new carbonising plant at Hemsworth, in Yorkshire, which will be one of the principal sources of the new gas grid constructed in the West Riding. At this plant coal gas of consistent quality is being produced at the pithead and supplied through high-pressure pipes to sixteen distributing centres. The plant has an initial capacity of 5½ million cubic feet per day, and has cost about £350,000 to build and equip.

IRON AND STEEL PRODUCTION.—An estimate of world iron and steel output in January to June last, as compared with the corresponding period of last year, made by the Wirtschaftsgruppe Eisen schaffende Industrie, Berlin, and reproduced in the *Iron and Coal Trades Review*, indicates that the output of pig iron advanced by 7,100,000 metric tons, or 17·8 per cent., to 47,096,000 metric tons, and that of steel by 11,300,000 metric tons, or 21·7 per cent., to 63,445,000 metric tons, as against the 1938 half-year.

RECORD BRITISH MOTOR EXPORTS.—Exports of British cars and chassis during the seven months ended July 31st, 1939, reached a record total of 49,234 vehicles; 8368 trucks, buses and tractors were also exported. The Empire was the biggest purchaser, with Australia taking 14,329 cars, New Zealand 10,124, South Africa 3014, India 2025, and other British countries purchased 8879. Foreign countries increased their purchases by over 3000 units to a total of 10,873, of which Denmark took 3470. The total value of the motor export trade during the period was over £9 millions sterling.

LOANS FOR ELECTRICAL SUPPLY PURPOSES.—During the four weeks ended August 12th the Electricity Commissioners sanctioned the borrowing by public authorities (joint electricity authorities, joint electricity boards, and local authorities) for electricity supply purposes of a total sum of £2,077,145. The total includes the following individual sanctions:—£600,000 for plant and building extensions at the Roath generating station of the Cardiff Corporation, and £300,000 for plant and building extensions at the Townmead Road generating station of the Fulham Metropolitan Borough Council. The total amount sanctioned during the period April 1st to August 12th was £8,964,519.

CONCRETE PIPE AIR-RAID SHELTERS.—An unusual method has been used at the works of Steel, Peech and Tozer and Co., Ltd., in the construction of an air-raid shelter of concrete pipes let into a disused slag heap; 72in. diameter concrete pipes, supplied by Stanton Ironworks Company, were used. In building the shelters one pipe was placed on wooden skids with its end against the base of the slag heap, and about 1ft. of material in front of it was then excavated. The pipe was then pushed forward by jacks as far as it would go and the operations were repeated until it was completely buried. A second pipe was then inserted behind it and jacked forward in the same way, and it was followed by successive pipes until a shelter 32ft. long was completed. A second parallel shelter was then built and the two joined up at the extreme ends and the outer ends closed by concrete end slabs with steel doors.

SURFACE ROUGHNESS.—A proposed surface roughness standard, prepared under the sponsorship of the Society of Automotive Engineers and the American Society of Mechanical Engineers with the approval of the American Standards Association, has been offered to industry in the United States for criticism and suggestions. In it surface deviations are divided into surface flaws, such as scratches, cracks, and holes, waviness and roughness. Waviness is described as a kind of surface deviation which consists of recurrent or random irregularities in a surface which have the form of waves. Roughness is defined as random or recurrent irregularities in a surface which have the form of small waves or bumps; it may be considered as being superimposed upon a nominal or a wavy surface. The proposed standards are expressed in terms of the root mean square average of the surface profile deviations in millionths of an inch, or microinches.

Air and Water

NEW NAVAL MINESWEEPERS.—The twenty minesweeping trawlers added to the Admiralty's 1939 construction programme will be each named after a tree, and will be known as the "Tree" class.

DEATH OF MR. P. A. S. FRANKLIN.—The American shipping industry has sustained a severe loss in the death of Mr. Philip A. S. Franklin, former President of the International Mercantile Marine.

RAILWAY AIR SERVICES.—Since the inauguration of Railway Air Services five years ago, its machines have flown 2 million miles and carried 25,000 passengers and over 750 tons of freight without a mishap.

NEW BATTLESHIP ORDERED.—Subject to the settlement of certain details, the Admiralty has decided to entrust the construction of a battleship of the 1939 programme to John Brown and Co., Ltd., Clydebank.

PROPOSED IMPROVEMENTS AT GREENOCK.—The Greenock Harbour Trust has under consideration a scheme for the reconstruction of Prince's Pier, and the improvement of the Garvel graving dock, at an estimated cost of £140,000.

NEW RUSSIAN AEROPLANE.—Reports from the U.S.S.R. state that a new monoplane, with a wing span of over 200ft., has completed its final tests. It is propelled by six engines, aggregating 8000 H.P., and is capable of carrying a crew of eight with sixty-four passengers.

ELECTRIC ARC WELDING ELECTRODES.—The British Corporation Register of Shipping and Aircraft has issued a new list of electrodes approved for electric arc welding. The list contains the names of twenty-four makers at home and abroad and particulars of sixty electrodes.

NAVAL CONSTRUCTION.—At the launch of the 8000-ton cruiser H.M.S. "Kenya" at Govan, Rear-Admiral B. A. Fraser pointed out that 245 ships, aggregating nearly 1 million tons, and mounting 1100 guns ranging from 4in. to 16in., were at present under construction for the Royal Navy.

NEW RIVER PORT IN LENINGRAD.—Preparatory work has been commenced on the construction of a new river port in Leningrad. The aggregate length of moorage in the new port will be about 7 miles. Many motor roads, railways, and tramways will run directly to the new port, in which all loading and unloading operations will be mechanised. A big passenger station will also be built. Constructional work on the first section of the new port, it is estimated, will cost 16 million roubles.

NEW HOLLAND–AFRICA MOTOR LINER.—A new twin-screw motor liner "Klipfontein" has just entered service on the Holland–Africa line of the United Netherlands Navigation Company. She is the first of three new sister ships, and her leading dimensions are as follows:—Length, 520ft.; breadth, 62ft. 6in.; and depth, 38ft. 3in. With a gross registered tonnage of 10,825, she has a displacement of 18,400 tons. Propelled by oil engines developing 11,800 B.H.P., the ship is intended for a service speed of 17 knots.

R.A.F. AND AIR MAIL.—A committee has been set up by the Air Ministry to consider the practicability of lending Royal Air Force machines to Imperial Airways for the carriage of mails over certain of the Empire routes. The idea, if adopted, would be a temporary one to enable the Service machines to tide Imperial Airways over the pre-Christmas rush period and to make available more passenger accommodation. It follows the recent decision of Imperial Airways to curtail passenger bookings on Empire routes, because of a scarcity of machines and pilots, in order that mails may be carried.

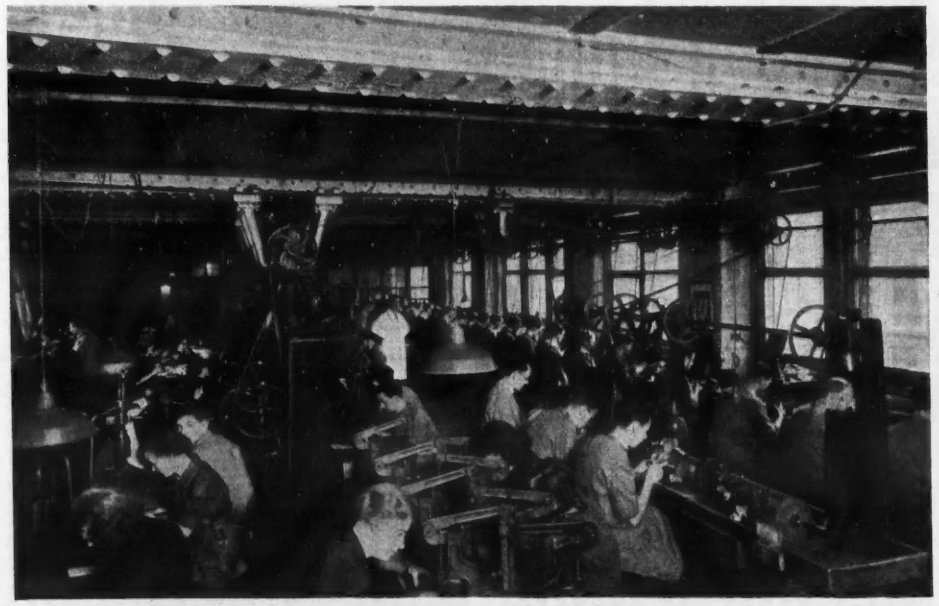
NEW WATER SPEED RECORD.—A new world record for water speed was set up by Sir Malcolm Campbell on Saturday, August 19th, at Lake Coniston. Timed over a statute mile in opposite directions, his motor boat "Bluebird II" attained a mean speed of 141·74 miles an hour. This craft is similar in design to that used previously, but is larger, having a length of 28ft. with a beam of 10ft. 10in. On the record-breaking attempt it was propelled by a twelve years old Rolls-Royce engine which was originally intended for use on experimental runs, and was to be replaced by one of 2500 H.P. for the final attempt. It is reported that Sir Malcolm is not going to try at present to improve upon the new record he has set up.

SALVING OF THE "THETIS."—An official statement of the Liverpool and Glasgow Salvage Association in connection with the salvage of the "Thetis" says that the work of refitting the salvage steamer "Zelo" at Cammell Laird and Co.'s Birkenhead dock is proceeding according to plan, and the "Zelo" was ready to sail to the scene of salvage operations on Thursday afternoon, August 24th. Some days will elapse before the preparations for the lift are complete. H.M.S. diving ship "Tedworth" and the Association's steamer "Ranger" left Liverpool on August 22nd for the scene of salvage operations. Their work consists of clearing away wire *débris* round the submarine which has impeded the work of the divers on the reeving and lifting wires.

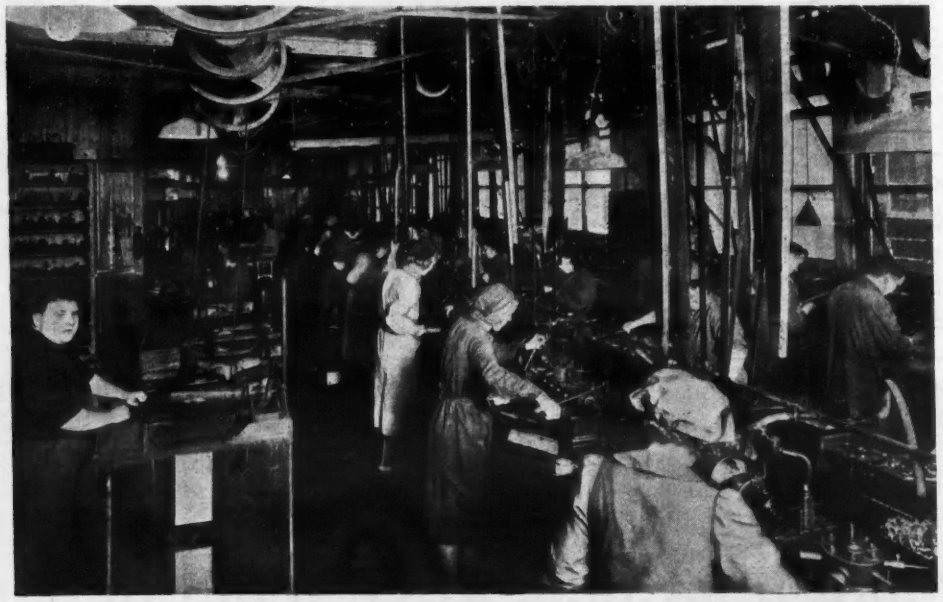
NEW AMERICAN MERCHANT SHIPS.—The United States Maritime Commission has tentatively accepted a tender for the construction of four "C-1" single-screw cargo ships. According to the *Journal of Commerce and Shipping Telegraph*, the tender was made by the Consolidated Steel Corporation of Los Angeles, and the bid of 1,890,000 dollars each for the ships was made on an adjusted price basis for the construction of full scantling type steam-propelled vessels. The "C-1" vessels will be 416ft. overall, 60ft. broad, have a displacement of 12,875 tons, and be propelled by engines of 4000 S.H.P. to give a speed of 14 knots. The placing of the order will bring the total of new ships ordered by the Commission, either for its own account or in co-operation with private operators, to seventy. Of them, sixteen have already been launched, including six tankers, nine "C-2" dry cargo ships, and one constructed for a private operator.

FOUNTAIN PEN WORKS OF CONWAY STEWART AND CO., LTD.

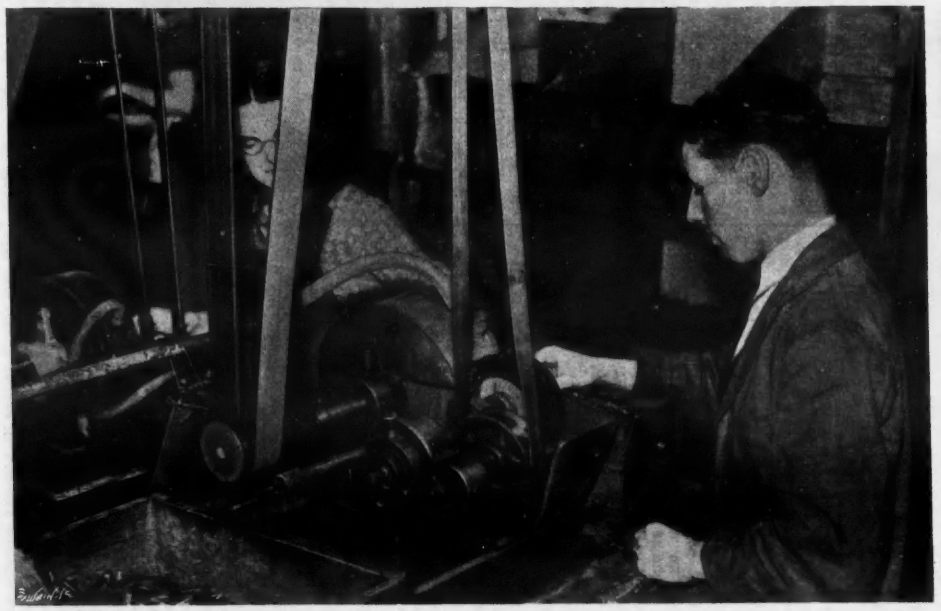
(For description see page 204)

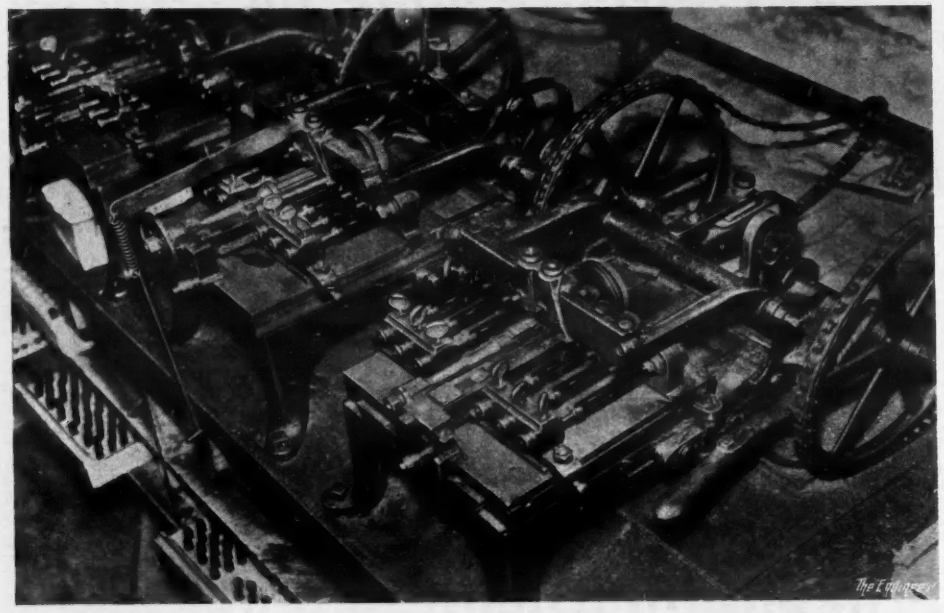


GOLD NIB MANUFACTURE
CENTRELESS GRINDING MACHINE



MACHINING SHOP
ENGRAVING MACHINES





The Engineer

AUGUST 25, 1939

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BI-MONTHLY SUPPLEMENT—"THE METALLURGIST"

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The Metallurgist

THE AUGUST NUMBER OF

THE METALLURGICAL SUPPLEMENT TO

"THE ENGINEER" ACCOMPANIES THIS ISSUE.

HIGH-SPEED LOCOMOTIVES

WE feel sure that the particulars given in our impression of July 21st of the huge locomotive recently completed by the Pennsylvania Railway at the Altoona shops will have been examined with interest by our readers, for it is safe to say that this new design constitutes a development in size and potential power exceeding anything previously accomplished—at any rate so far as steam locomotives specially built for high-speed passenger trains are concerned. The engine has been constructed to operate passenger trains of 1200 tons, at a maximum sustained speed of 100 m.p.h. on a straight level road. To meet this requirement the estimated maximum cylinder horse-power is 6500. The appearance of this remarkable engine, following so closely the report on passenger locomotive tests issued by the Association of American Railroads, is of particular interest. That report, published in October last year, deals in an informative manner with a series of trials carried out to determine the draw-bar horse-power required to haul 1000-ton trains on a straight level line at a constant speed of 100 m.p.h., and was authorised by the Mechanical Division of the Association in connection with a study of the further development of the reciprocating steam locomotive.

The test runs were made on the Pennsylvania, the Chicago and North-Western, and the Union Pacific Railways, and involved the use of 4–6–2, 4–6–4, and 4–8–4 type engines on these three railways respectively. Actually the train, which was the same throughout all runs, weighed 1005·2 tons, and consisted of fifteen eight-wheeled vehicles and a dynamometer car, giving a mean weight of 62·8 tons per car. On each of the three lines high-speed tests were made on the most suitable lengths as regards gradients and curvature, although only on one line, the Union Pacific, was a speed of 100 m.p.h. attained, and on that line the eight-coupled engine reached a speed of about 102 m.p.h. on a falling gradient of 0·13 per cent., or 1 in 770. As a result of these experiments several important facts have been brought to light regarding the problem of handling heavy high-speed trains at 100 m.p.h. It was established that the horse-power required at the tender draw-bar is 3379, which means a pretty big engine. Be that as it may, however, this is by no means a real measure of the power necessary, for it is one thing to haul the train when it is once at speed and entirely another to get such trains up to the speed required. It is this aspect of the problem that is the most serious. The Union Pacific locomotive actually handled the 1000-ton train at 100 m.p.h., but it was noted that even on a falling gradient of 0·13 per cent. it required seven minutes to lift the train from 80 to 100 m.p.h. Further, calculations indicated that had the train been running on the level the engine would have required sixteen minutes to reach 99 m.p.h., and that this speed would have been the maximum unless a greater power could have been obtained from the locomotive. Pursuing this side of the question further, computations established the fact that to attain a speed of 100 m.p.h. on the level within a reasonable space of time would require a maximum of 6000 draw-bar horse-power to accelerate the train from starting to 100 m.p.h. in approximately twelve minutes, while if 7000 H.P. were available then just under nine minutes would suffice.

Enough has been said to show that if very heavy trains are handled at the higher speeds large-capacity engines will be required, for all operating men know that the attainment of high speeds can only be accomplished by having a large reserve of power for rapidly accelerating the train up to speed after the inevitable slow-downs, to say nothing of unforeseen stops occurring on busy lines. A further point brought out during these tests was that, in the case of the locomotives used, in no instance was the speed limited by the boiler capacity, implying that the attainment of greater power was entirely limited by the failure of the cylinders to maintain the required mean pressure. In other words, at high speeds the limit is reached when the steam generated cannot be passed through the cylinders with sufficient rapidity. The throttling during admission and the building up of back pressure during exhaust set a limit to the mean pressure and thus restrict the cylinder horse-power, which can only be overcome by the provision of large valves and portways, together with the use of high-pressure superheated steam. In this connection it will have been noted that the new Pennsylvania engine has 12in. valves for the 22in. cylinders, a valve size used for the former K.4s "Pacifics" with 27in. cylinders. Experience both here and in the United States has amply justified the use of steam at the higher pressures for fast-running engines; it would seem, however, that to attain the full benefit expected great attention should be given to the superheater on account of the increased density of the steam. Superheated steam flows more readily through the ports than saturated, and steam at, say, 200 lb. pressure, and carrying a superheat of 300 deg. Fah. has a specific volume of 3·12 cubic feet per pound, while at 300 lb. pressure with equal superheat the specific volume is reduced to about 2·16; in other words, its density is increased by nearly 45 per cent. With this in mind, therefore, it would seem that efficient superheater equipment is one of the desirable features of reciprocating steam locomotives intended for high-speed operation. Further, while steam pressures of 250 lb. or 300 lb. per square inch are more suitable than lower pressures, their greatest advantage lies in the smaller cylinders required, which in turn render it possible to use relatively large valves and steam ports, in proportion to the cylinder volume.

Heat and Work

BEFORE the science of thermodynamics had acquired much importance, the conception of total heat was a simple one. In the case of steam, for example, if one took the heat required to raise a pound of water to the temperature of evaporation, and added to this the heat necessary to evaporate it, and to do any subsequent superheating, the figure so obtained was called the total heat of a pound of steam at the final temperature and pressure. This definition served well enough for many years. Knowing the total heat in a pound of steam and the weight of steam used per hour by a given engine, it was easy to estimate the weight of coal required for the power developed, and this was the important thing in the early days of the steam engine. In course of time, this old idea of total heat and its usefulness gave place to a new conception. The equivalence of heat and mechanical work obviously made it possible to express the work which a pound of steam was capable of doing by the "heat drop," or the difference in the amount of its total heat before and after the operation. The centre of interest no longer lay in the question of how much heat from a furnace went to the making of a pound of steam. It was transferred to that of the quantity of work available from steam of a given pressure and temperature. The total heat therefore came to be regarded as a property of the steam, by virtue of which it was enabled to do work. In accordance with this view, the definition of the term had to be slightly modified so as to include the heat equivalent of the work required to pump a pound of water into the boiler in the first place. This addition was extremely small; indeed, quite negligible for the pressures in use a generation or two ago, but in the interests of accuracy it had to be regarded. It might have been included by merely adding the quantity to the sensible and latent heats of the steam, but it was more convenient for the new outlook to consider total heat from a fresh standpoint, namely, as made up partly of the heat represented by the internal energy of the steam and partly of the heat equivalent of the product of its pressure by its volume. Expressed symbolically, it was stated as $E+P\,V/J$, and the mathematician was satisfied. The engineer, however, sought for some sort of reality behind these symbols. Pressure and volume were familiar to him, and the product $P\,V$ could evidently be regarded as the work done by a pound of steam in so far as finding room for its existence was concerned. Alternatively, it could be looked upon as the work done by a pound of steam in forcing its way into a place against a constant pressure P, while the term E could denote the additional work that the steam could do if it were allowed to expand adiabatically down to a pressure corresponding to the freezing point of water. Considered in this way, the analogy between total heat and the work shown by an indicator diagram could be perceived. The total heat $E+P\,V/J$ could evidently be pictured as the area of a theoretical indicator diagram for a pound of steam, $P\,V$ being the work done in the cylinder to the point of cut-off, and E being the area lying under the expansion curve. If we draw a horizontal line through such a diagram, the latter may be regarded as representing the combined diagrams of a compound engine, so that the upper part may be considered as depicting the work done by an engine working between two given pressures, while it shows at the same time the fraction of the total heat that is absorbed in doing the work.

This graphic correlation between total heat and available work allows the engineer to perceive some physical meaning in the term heat drop, by demonstrating its equivalence to the work done. To the academic mind, however, which does not wish to look beyond its symbols and the rules of algebra, physical illustrations are superfluous. The First Law of Thermodynamics tells us that the units of heat and work are interchangeable in a fixed ratio,

and this being granted, it followed that work could be produced by the consumption of an equivalent amount of heat. The engine in which the work was done was called a "heat engine," and was supposed to be driven by the heat which disappeared in the process. A quantity of heat was designated by some symbol, generally the letter Q, and having been so labelled, it was treated as if it were some entity enjoying an independent existence in its own right, and were capable of pushing a piston along or maintaining the torque on the rotor of a turbine. It may, at times, be convenient for purposes of calculation to regard heat in this way, but the conception is a highly artificial one. Heat cannot exist apart from some substance that is hot, but as, under certain circumstances, it can be added to a substance without increasing the temperature of the latter, it is clear that heat cannot be a function of the temperature alone. It is therefore sometimes defined as the product of temperature multiplied by entropy, but this definition introduces another quantity more useful for purposes of calculation than attractive from its appeal to the understanding. There is, indeed, no very intelligible physical meaning that can be given to entropy, for although Planck has laboured to show that it is numerically equal to the universal gas constant multiplied by the logarithm of the probability of some particular state, it can hardly be said that this makes its nature much clearer. The argument would, no doubt, have more success if its exponents would explain exactly what is meant by the probability in question, and how it can be computed. But, whether entropy be considered as a measure of the unavailability of heat or as the equivalent of some mathematical expression or merely as a number to be found in the steam tables, it is certainly not anything that will drive an engine, whether multiplied by temperature or not.

The fact of the matter is that heat, however it may be defined, never drove an engine and never will. The only thing that will make anything move is pressure of some sort, and the only way that mechanical work can be done in an engine is by a pressure acting over a distance. No amount of heat will make a piston move. If pressure be associated with the heat, work may be done, but an equal pressure acting through the same distance would do precisely the same work without any heat at all. Heat can do no more than constitute a fund of energy, by means of which the pressure can be maintained as the volume of the working substance increases. The fund becomes exhausted, for practical purposes, as soon as the draft on it has reduced the temperature to that of the surrounding atmosphere; for any further expansion, even though pressure were available for it, would have to be paid for by returning an equivalent amount of heat to the substance in order to restore it to its original condition. The old concept of a steam engine or an I.C. engine as a pressure engine, which it really is, instead of as a heat engine, which it is only indirectly, has the advantage of keeping the mind fixed upon measurable quantities, such as pressure and volume, and if it relegates other important functions, such as total heat, internal energy, entropy, &c., to a subordinate position, it is merely because they have no direct connection with the working of the engine.

The Sliding of Metals, Frictional Fluctuations, and Vibration of Moving Parts

By F. P. BOWDEN, L. LEBEN, and D. TABOR*

RECENT experiments (Bowden and Leben, 1937, 1939) have shown that the frictional force between moving metals may not remain constant during sliding. Sliding is not a continuous process. The motion may proceed by a process of "stick and slip." Most of the earlier methods of measuring friction do not record these fluctuations because the measuring system usually possesses a high inertia so that only the average frictional force is recorded.

In the apparatus employed in these experiments the lower surface was a flat metal plate which was driven at a uniform rate by a water piston. The upper surface, which rested on the plate, was a small curved metal slider, which was attached to a high-frequency device for measuring the frictional force. This force could be recorded photographically in a moving film camera, so that any rapid fluctuations which occurred in it could be measured. Experiments with various metals sliding together showed that violent fluctuations do, in fact, occur in the friction.

Three Types of Sliding

The exact behaviour depends upon the relative physical properties of the metals, particularly on the melting point, and there is evidence that three distinct types of sliding can occur.

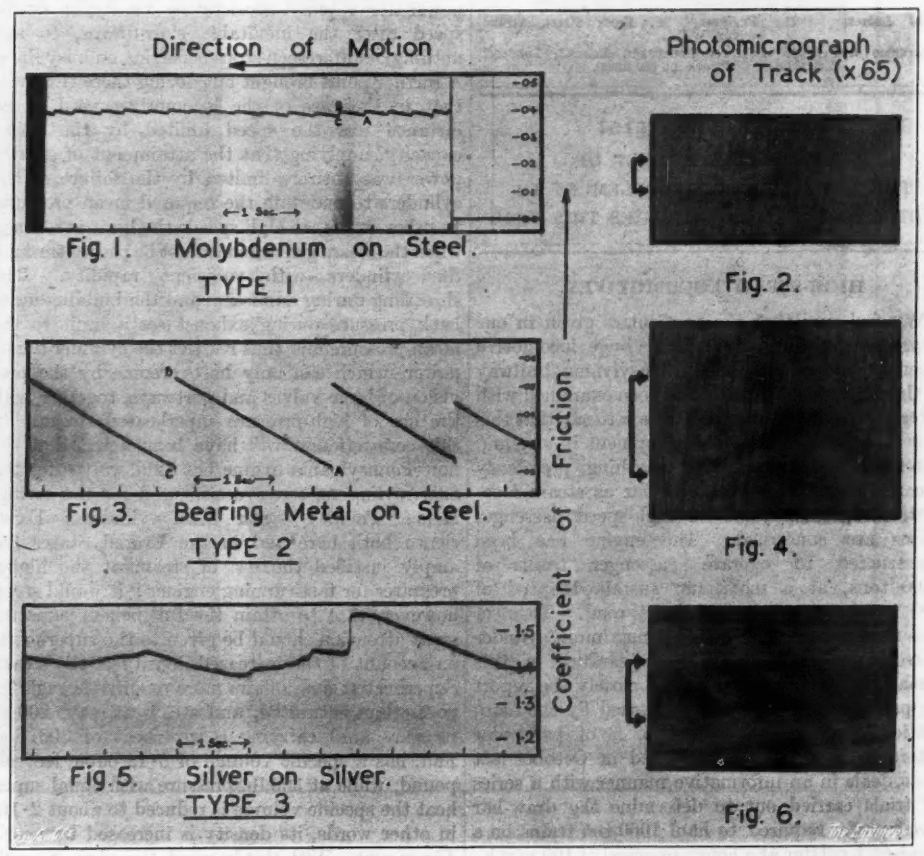
Type 1 occurs when a hard high melting metal slides on a softer one of lower melting point. A typical result obtained when molybdenum slides on steel is shown in Figs. 1 and 2. The first of these figures shows the frictional behaviour during sliding. In this and the following traces the passage of time is from right to left. It will be seen that the frictional force is fluctuating violently and these fluctuations all consist of a period A B during which the tangential force is increasing steadily, followed by a very rapid fall B C. A measurement of the slope of the line A B shows that the top surface is moving forward with the same velocity (0·003 centimetres per second) as the bottom one, *i.e.*, there is no relative motion of the surfaces. They are sticking together. Suddenly at B a very rapid slip of the upper surface occurs. When the tangential force has fallen to C the surfaces again stick, and the process is repeated indefinitely. It is clear that motion takes place by a process of "stick and slip." A photomicrograph of the track formed on the lower surface is given in Fig. 2. It will be seen that a well-defined track (indicated by the arrows) was torn out of the softer lower melting metal. The surface of the high melting metallic slider was not perceptibly changed, however. The behaviour of the friction and wear were essentially the same when other hard high melting metals slid on softer metallic surfaces of lower melting point.

In type 2, which is characteristic of a low melting metal sliding on a harder one of higher melting point, the behaviour is different. Figs. 3 and 4 show the results for a bearing metal sliding on steel. The frictional behaviour is shown in Fig. 3, and it will be seen that motion is again proceeding by a process of stick and slip (A B C). Comparison with Fig. 1 shows, however, that the slips are much larger than for sliding of type 1. A photo-micrograph of the track formed on the flat surface of the high melting metal is given in Fig. 4. This surface is apparently undeformed, but very small blobs and smears of the low melting metal are wiped on to it. Essentially similar results were obtained when other soft low melting metals slid on harder surfaces of higher melting point.

The behaviour when identical surfaces slide together (type 3) is, however, very different. The frictional behaviour of silver sliding on silver is given in Fig. 5. The friction is very much higher than in the previous cases and large fluctuations occur in it. A very sudden rapid slip no longer occurs, but the fluctuations are much slower and very irregular. The nature of the track formed is shown in Fig. 6. It is clear that this track is quite different from either of the two tracks formed by dissimilar metals. A groove is formed in the flat surface, but it looks very different from the groove cut by a metal of higher melting point. The general appearance would suggest that the metal within the groove has flowed during sliding and then solidified. This third type of behaviour is characteristic of similar metals, whatever their hardness or melting point.

These observations show that the "classical laws" of friction can be regarded only as approximations. First, it was assumed that the sliding of two solids is continuous. It is clear that motion is discontinuous, and in many cases kinetic friction can be regarded as a series of static frictions. Furthermore, according to previous theories only the surface atoms of the sliding solids are involved (Hardy, Tomlinson). The results, however, show that when sliding occurs the metal is distorted to a considerable depth. Kinetic fricton is therefore not a purely surface phenomenon, and any complete theory must also take into account the bulk properties of the solids.

It is clear that an intermittent clutching and breaking away of the metals is taking place during sliding, and the results suggest that the resistance to motion arises from the fact that metallic junc-



Type 1 is for a high melting metal on a soft low melting metal; small stick-slips and cut track. Type 2 is for a soft low melting metal on a hard high melting metal; large stick-slips and smeared track. Type 3 is for identical homogeneous metals; large and irregular friction and torn track. Type 3 gives the greatest friction and wear.

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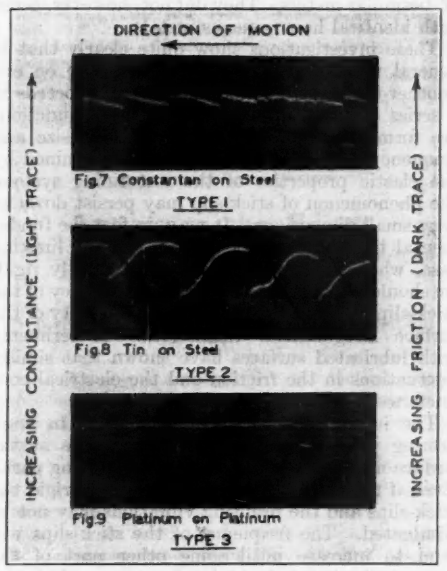
tions whose dimensions are large compared with the dimensions of a molecule are being rapidly formed and broken. The force necessary to break these junctions is the frictional force. Experiment has also shown that even if the surfaces are lubricated with mineral oils or other lubricants, the behaviour may be essentially the same and an intermittent clutching and breaking away of the metallic surfaces occurs through the oil film.

More recently, Papenhuyzen (1938) in some work on the friction of motor-car tyres has also observed a discontinuous motion in the sliding of rubber.

THE REAL AREA OF CONTACT AND THE TEMPERATURE OF SLIDING SURFACES

The above view of the mechanism of sliding has been confirmed by the measurements of the electrical conductance between surfaces that have been carried out by Bowden and Tabor (1939). Experiments with stationary surfaces have shown that the area of intimate contact between the surfaces is very small, and may be less than one



In Type 1 the conductance increases during the stick and falls at the break; the upper surface ploughs its way through the lower. In Type 2 the conductance decreases during the stick and rises after the slip; the upper surface welds on to the lower and the junctions are pulled out. In Type 3 the conductance is high and fairly steady; both surfaces contribute equally to the formation of the metallic junctions.

ten-thousandth of the apparent area (see also Holm). No surface, however carefully prepared, is quite flat, and the general behaviour suggests that the surfaces are held apart by the small irregularities. In consequence, the local pressures at the points of contact will be very high, and may be sufficiently great to cause the steel to flow plastically. By this means junctions will be formed between the metals whose cross-section is sufficient to enable them to support the applied load. In a similar way plastic flow of the metals with the formation of junctions between the surfaces will occur when the surfaces are sliding one against the other.

Earlier experiments (Bowden and Ridler, 1935, 1936) have shown that the surface temperature of sliding metals is surprisingly high, and may easily reach the melting point of the surfaces, although the mass of the metal remains quite cool. Both theory and experiment show that at very low speeds the temperature rise is small, but at sufficiently high speeds softening and melting will occur at the points of contact between the sliding solids. At appreciable speeds this high temperature will be an important factor in the formation of metallic junctions between the surfaces and in affecting the friction, wear, and surface flow. In this connection the important factor is not the relative mechanical properties of the metals at room temperatures, but the relative mechanical properties at the high temperatures reached during sliding. The observed temperature rise is in reasonable agreement with the approximate theory. More recently, Blok (1937), using the same method, has confirmed the existence of these local high temperatures, and has made a more exact calculation of the temperature rise.

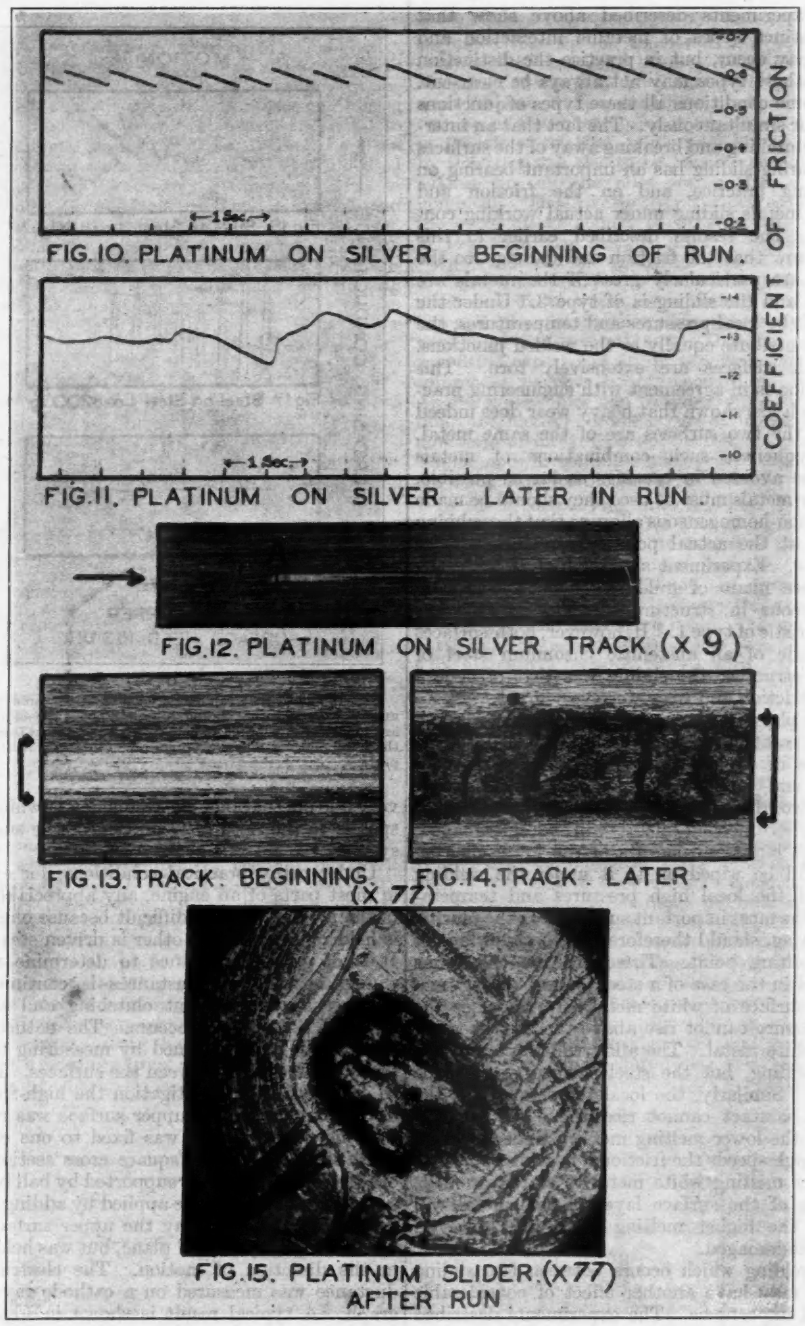
The results of conductance measurements with moving surfaces (Bowden and Tabor, 1939) show that three types of junction can occur, corresponding to the three types of sliding described above. In the case of a curved slider of a high melting metal sliding on a lower melting metal (type 1), the electrical conductance and therefore the area of intimate contact increases during the stick. The moment a slip occurs there is a sudden decrease in the conductance. A typical example for constantan sliding on steel is given in Fig. 7. The result suggests that the irregularities on the hard high melting metal penetrate the softer one and resistance to motion is due mainly to a ploughing out of the softer metal.

In the case of a low melting metal sliding on a metal of higher melting point (type 2), the conductance decreases during the stick and the moment after slip occurs it rises to a maximum value. Fig. 8 shows the results for tin sliding on steel. The result supports the suggestion that the local high pressures weld the softer lower melting metal on to the surface of the other. If the sliding speed is appreciable, this welding or soldering will be greatly assisted by the local high temperatures, and in some cases by the actual melting of the metal. The area of contact is at a maximum just after the slip. During the stick the increasing pull will draw out these junctions thinner and thinner until they suddenly break when slip occurs and the process is repeated. The high melting metal is therefore left untouched with very small blobs of the "solder" adhering to it.

When two similar metals slide together (type 3), the conductance is high and remains much more constant during sliding. The results for platinum sliding on platinum are given in Fig. 9. The local pressures and temperatures will cause a flow of both surfaces which will now contribute equally to the welded junctions. When movement occurs, both surfaces will be damaged and the metal in the resulting track will be badly distorted and torn.

DISSIMILAR METALS: THE CHANGE FROM TYPE 1 TO TYPE 3

Interesting results were obtained when platinum was slid on silver. The frictional behaviour at the beginning of the run is shown in Fig. 10, and it will be seen that small stick-slips were occurring. At the same time a cut track was formed in the silver surface, as shown in Fig. 13. Comparison with the previous figures shows that the sliding was characteristic of type 1 for dissimilar metals. As the motion proceeded, however, the nature of the sliding gradually changed until a very different type of sliding was occurring. The friction increased from $\mu=0{\cdot}6$ to $\mu=1{\cdot}5$, and the final frictional behaviour is shown in Fig. 11. It will be seen that slow and irregular fluctuations were now occurring in the friction. Corresponding to this change in the frictional behaviour there also occurred a change in the nature of the track. This is clearly shown in the photo-micrograph given in Fig. 12. The track begins at A, and it will be seen that it was at first that of type 1. Gradually, however, it changed until a very different type of track was being formed. This latter part of the


COEFFICIENT OF FRICTION
1 Sec.
FIG.10. PLATINUM ON SILVER. BEGINNING OF RUN.
FIG.11. PLATINUM ON SILVER. LATER IN RUN.
FIG.12. PLATINUM ON SILVER. TRACK. (X 9)
FIG.13. TRACK. BEGINNING.
FIG.14. TRACK. LATER. (X 77)
FIG.15. PLATINUM SLIDER. (X 77) AFTER RUN.

At first the friction and track correspond to the characteristic of dissimilar metals (platinum on silver). After a short time both change over to the characteristics of similar metals. Silver has been picked up from the lower surface, and has formed a welded blob at the tip of the platinum slider.

track is shown under higher magnification in Fig. 14. Comparison with earlier figures shows that the final behaviour of the friction and wear was that characteristic of type 3, obtained when similar metals slide together.

At the conclusion of the experiment the upper

slider was examined under the microscope. The photo-micrograph obtained is reproduced in Fig. 15, and it will be seen that a small metallic blob had formed on the platinum surface. This blob consisted of silver transferred from the lower surface during the sliding. The final sliding was therefore in reality not platinum on silver, but silver on silver. This explained the change in the frictional behaviour from that of dissimilar metals to that characteristic of similar metals.

An essentially similar change in behaviour was observed with copper sliding on silver. Again, the sliding changed over to that characteristic of similar metals, and close examination showed that again silver had welded on to the copper surface. In this case the high metallic lustre of the blob stood in marked contrast to the dull colour of the surrounding copper, showing quite clearly that the blob consisted of silver transferred from the lower surface.

The silver blob which formed on the upper slider during the course of the sliding was not torn off under the action of the large frictional forces that were acting. This blob must therefore have been firmly welded on to the upper slider. It is clear that these observations strongly confirm the view that welding can occur between sliding metals.

Practical Implications

The experiments described above show that three distinct types of metallic interaction and sliding may occur, but in practice the distinction between these types may not always be clear-cut. Under some conditions all these types of junctions may occur simultaneously. The fact that an intermittent clutching and breaking away of the surfaces occurs during sliding has an important bearing on engineering practice, and on the friction and wear of metals sliding under actual working conditions. The results described earlier in this article show that the friction and damage to the surfaces are particularly great if the metals are identical and the sliding is of type 3. Under the action of the local pressures and temperatures, the metals contribute equally to the welded junctions, and both surfaces are extensively torn. This observation is in agreement with engineering practice, which has shown that heavy wear does indeed occur if the two surfaces are of the same metal. In consequence, such combinations of metals should be avoided in bearings as far as possible. If similar metals must be used they should be made of some non-homogeneous alloy, so that the rubbing surfaces at the actual points of contact will be dissimilar. Experiment showed that if both surfaces were made of mild steel which was non-homogeneous in structure the sliding was that characteristic of type 1. If, however, both surfaces were made of an austenitic chromium steel of uniform structure the sliding was that of type 3 and the friction and wear were very great.

If the physical properties, and particularly the melting points of the two metals, are different, junctions of type 3 cannot be formed, and the friction and wear of the surfaces will be less. When two dissimilar metals slide together, the hard higher melting metal will be undamaged, but small blobs and smears of the lower melting metal will be wiped on to it under the welding action of the local high pressures and temperatures. The most important surface, *e.g.*, the journal in a bearing, should therefore slide on a surface of lower melting point. These are the conditions that hold in the case of a steel journal sliding on a bearing surface of white metal. In this case the local pressure cannot rise above the flow pressure of the white metal. The alloy will therefore flow during sliding, but the steel surface will not be affected. Similarly, the local temperature at the point of contact cannot rise above the melting point of the lower melting metal. Hence at sufficiently high speeds the frictional heating will cause the lower melting white metal to soften or melt, and flow of the surface layer of this metal will occur. The higher melting steel will, however, remain undamaged.

The welding which occurs between two sliding surfaces may have another effect of considerable practical importance. The experiments described above have shown that when two dissimilar metals slide together, the adhesion of one surface on to the other may change the sliding to that of two similar metals. In consequence there will occur a marked rise in the friction and wear between the surfaces. This will clearly be of great practical significance, since it is obvious that such a change will be extremely dangerous in any bearing. Indeed, an effect of this kind may be at the root of certain hitherto inexplicable cases of failure in bearings.

So far, "pick-up" effects of this magnitude have only been observed with various sliders on silver. It is perhaps significant to note that silver has only a very thin oxide layer, and it is possible that this is the reason that silver shows a great readiness to weld itself on to the other sliding surface. Other factors may, however, come into play, such as the mutual solubility of the metals or some similarity in their chemical behaviour. The surface tension of the metals and that of their oxide films may also be important. A detailed investigation of this problem might yield information of great practical importance.

Frictional Fluctuations and the Vibration of the Moving Parts

The intermittent making and breaking of the metallic junctions suggests that fluctuations in the frictional force are of general occurrence. In all cases we should expect that junctions will be formed, strained, and suddenly broken in a distance depending on the elastic properties of the moving system. The stick-slips which are produced will set up vibrations in the moving parts. If the upper surface is suspended on a spring constraint which is heavily damped, the slips are quite sharp, as Fig. 3 shows. If, however, the damping is removed the slip shows a marked tail, composed of very fine fluctuations, the frequency of which corresponds to the natural frequency of the suspended system.

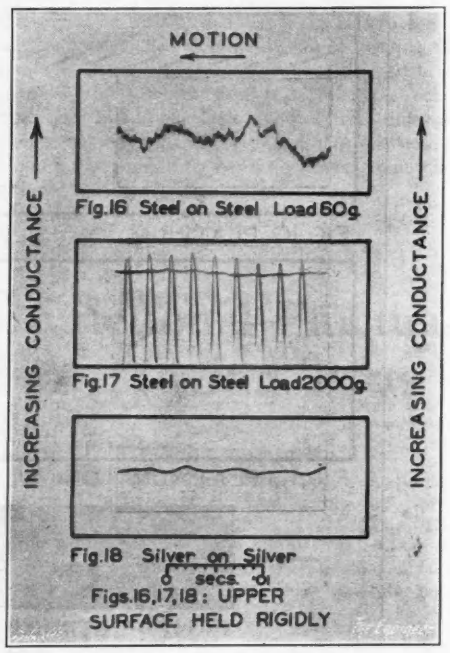


Fig. 16 shows that rapid fluctuations in the area of contact may still occur during sliding, although not if the sliding metals are identical and homogeneous (Fig. 18). Fig. 17 shows that these fluctuations may set up periodic vibrations in the moving parts.

Under many practical conditions, for example, in most parts of an engine, any appreciable arrest in the moving parts is difficult because one surface is held rigidly and the other is driven steadily on. It is of great importance to determine whether sliding in such circumstances is continuous, or whether an intermittent clutching and breaking away of the surfaces occurs. The nature of the motion can be determined by measuring the electrical conductance between the surfaces. In order to carry out this investigation the high-frequency device supporting the upper surface was removed and the upper surface was fixed to one end of a short steel bar of ½in. square cross section. The other end of the bar was supported by ball bearings, so that the load could be applied by adding weights to the bar. In this way the upper surface could move freely in a vertical plane, but was held rigidly in the direction of motion. The electrical conductance was measured on a cathode ray oscillograph. A typical result is shown in Fig. 16 for steel-on-steel with a load of 60 grammes. It is evident that fluctuations in the electrical conductance and hence in the area of contact still occur during sliding. These fluctuations are smaller than those observed with the spring constraint, but they occur in a very short period, certainly less than 10^{-4} sec. As the speed of the lower surface was 0·025 cm. per second the relative movement of the surfaces in this time is about $2 \cdot 10^{-6}$ cm. Although this relative movement corresponds only to the distance of several atoms, it is clear that a clutching and breaking away of the surfaces is occurring. This behaviour appears to be characteristic of dissimilar metals. If the metals were identical, so that the sliding was of type 3, these rapid fluctuations were not observed. A typical result for similar metals is shown in Fig. 18 for silver-on-silver. It is seen that the conductance changes are small and relatively smooth.

Some measurements were also made with much heavier loads. With a load of 2000 grammes, for example, in the case of steel-on-steel, the surfaces emitted a characteristic squeak and the conductance measurements showed clearly marked fluctuations (Fig. 17), the frequency of which corresponded to that of the emitted noise. A simple calculation showed that this was roughly equal to the natural frequency, at that load, of the ball-bearing shaft supporting the bar to which the upper surface was attached. These vibrations were clearly set up in the shaft by the stick-slip fluctuations between the surfaces. These large fluctuations were observed for other combinations of dissimilar metals. They did not, however, occur with identical homogeneous metals.

These investigations show quite clearly that in general when two dissimilar metals slide on one another the motion is not smooth, but proceeds in a series of jerks, during which metallic junctions are formed and broken. Although the size and frequency of these fluctuations are determined by the elastic properties of the restraining system, the phenomenon of stick-slip may persist down to very small dimensions. It may, in fact, be fundamental to the nature of sliding. In the limiting case, when the moving parts are perfectly rigid, we should expect that the size and frequency of the stick-slips will be controlled by the elasticity of the surface irregularities themselves. Experiments with lubricated surfaces have shown that similar fluctuations in the friction and the electrical conductance may occur as for clean metals.

The importance of these conclusions in engineering practice is clear. The stick-slips at the surface may set up vibrations in the moving parts. Even if the moving parts are made very rigid the stick-slips and the resulting vibrations may not be eliminated. The frequency of the stick-slips will tend to increase until some other part of the system vibrates at the higher frequency. Lubrication will not necessarily produce smooth motion. As we have already seen, lubricated surfaces may often behave in essentially the same way as unlubricated ones.

A crude examination of the moving parts of a running engine (*e.g.*, a piston sliding in a cylinder) might suggest that a smooth forward motion between the surfaces was taking place. The detailed analysis shows, however, that this is not the case. If we consider a piston sliding in a cylinder the minute stick-slips may set up vibrations in the piston. The amplitude and frequency of these vibrations is dependent on the natural frequency and the restraints of the moving system. The frequency may be high and this small rapid oscillatory motion will be superimposed on the minute stick-slips and may modify them. In addition, the piston will be moving bodily forward. The rate of this forward motion also influences the nature of the minute stick-slips and experiments show that in general the extent of the slip becomes smaller as the sliding speed increases. The resultant motion of the surfaces will be the sum of all three of these effects. It is clear that the exact form of this motion will be influenced by the nature of the metals themselves, because this determines the nature and extent of the minute stick-slips. It will be influenced by the mechanical properties of the system, such as the natural frequency, the moment of inertia, and the damping of the moving parts. Finally it will be influenced by the velocity of the main forward motion. It is this detailed motion which is responsible, to a large extent, for the frictional wear. These factors must be of great importance in determining the most suitable pairs of metals for sliding under different conditions of load, speed, and restraint.

Summary

An analysis of the kinetic friction between moving metals shows that it does not remain constant. The metals may move by a process of stick and slip, and the friction, area of contact, and surface temperature may all fluctuate rapidly during motion. The exact type of sliding depends upon the relative physical properties, particularly on the relative melting points of the different metals. There is evidence that the friction is due to the formation and subsequent breaking of

metallic junctions between the surfaces, and these junctions may be of three distinct types. The type characteristic of similar metals gives the highest friction and wear.

When dissimilar metals slide together one surface may pick up material from the other and the frictional behaviour may change over to that characteristic of similar metals.

The minute stick-slips inherent in the sliding may set up vibrations in the moving parts. The amplitude and frequency of these vibrations will depend on the mechanical properties and the restraints of the moving parts. The resultant motion between the surfaces will be complex and will be determined by the nature of the stick-slip, the natural frequency of the system, and the speed of the forward motion. It is this resultant motion which governs the friction and wear.

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Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

"PACIFIC" LOCOMOTIVES ON INDIAN RAILWAYS

SIR,—Although no copy of the actual report respecting the above has yet become available to me—and may not be for some little time—yet even without one I think comment is necessary on two points mentioned in your editorial in THE ENGINEER for July 14th, "Standard Locomotives on Standard Permanent Way."

You refer to a supposed countervailing disadvantage considered inherent in the "Pacific" (4–6–2) type of locomotive as against the 4–6–0, in that the former is likely to punish the track more than the latter and thus arrive at a balance "advantage of the wide fire-box against the disadvantage of the 'Pacific' wheel formation." There is, however, no reason whatever for the 4–6–2 type to be more punishing to the track than the 4–6–0, if properly designed with a view to the conditions to be met—that is to say, that a 4–6–0 type locomotive with a longer rigid wheel base will, in many circumstances, be harder upon the track than a 4–6–2 with a somewhat lesser rigid wheel base. There is therefore no ground for argument against the "Pacific" type locomotive with its more adequate fire-box compared with the disadvantage—when it comes to the fuel bill—of the 4–6–0 type with long, narrow fire-box.

Further on, in dealing with the actual engines, you make reference to "the apparent lack of co-operation between the responsible authorities in India and the consulting engineers and locomotive builders in this country." Regarding this point, I believe I shall be anything but alone amongst locomotive engineers having overseas service in stating that the lack of real knowledge of actual conditions on railways abroad which exists in many of the home circles referred to—although, be it noted, not in those of their foreign competitors—has always appeared remarkable. There appears to be a situation parallel with that which existed until recent years on the commercial side of English industrial concerns in regard to actual overseas conditions and your reference to "the degree of co-operation to be desired between responsible authorities abroad and the home engineers and builders being no easy matter to achieve in practice" would not be applicable if the appropriate steps were taken to correct the lacunæ which exist on the technical side of locomotive engineering in a similar manner to that followed in these later years on the commercial side of industry in respect to firms whose business comprises an appreciable proportion of overseas trade.

August 11th. MIDLOCO.

"DISTILLATION OF COAL BY ELECTRICAL MEANS"

SIR,—My attention has been called to an article in the May 12th, 1939, issue of your journal, entitled "The Distillation of Coal by Electrical Means." The article is interesting, and has been carefully prepared. However, there is an error in the third paragraph. The "350 B.Th.U." should be 530. This error, which is probably just a transposition of figures, results in the impression that the B.Th.U. in the form of gas per ton of coal is only 65 per cent. of that which it really is.

H. S. WALKER,
Supervising Engineer, Research Department.
The Detroit Edison Company,
2000 Second Avenue, Detroit, Michigan,
August 9th.

ELECTRICAL INSULATION IN MINES

SIR,—Referring to the report of the Royal Commission on Safety in Coal Mines (Cmd. 5890), mention is made on page 368 of the practicability of adopting some specified minimum standard of insulation resistance with which electrical apparatus in use in mines must comply. Furthermore, in the recent Presidential Address to the Association of Mining Electrical Engineers reference is also made to a possible difficulty in being able to comply with such a minimum standard, and a hypothetical condition of humidity to support this view point is quoted.

What appears to be overlooked in this connection is the fact that for a period extending over very many years no practical engineering difficulty has been encountered in complying with the similar regulation, for so long applicable, to practically every other industry in the country.

There is in coal mining no greater difficulty in being able to comply with a regulation specifying minimum insulation resistance than in the case of many other industries in which explosive dusts, fumes, heat, or humid conditions are prevalent or expected. What is the special difficulty in the coal-mining industry, if any?

RESEARCH.

August 21st.

Aircraft Fire-Fighting Equipment

IT has been officially announced by the Air Ministry that an automatic device, designed to prevent or to put out fire in the engine compartment of aircraft in the event of a crash or fire occuring during flight, is now being fitted as standard equipment to Royal Air Force aircraft, and that orders have been placed for the necessary equipment. We are indebted to the Graviner Manufacturing Company, Ltd., of First Avenue House, Holborn, London, W.C.1, and Oakley Works, Southfield Road, Acton Green, London, W.4, for details of the equipment, which was referred to and illustrated in our issue of August 4th at the close of our article describing the refuelling of aircraft in flight. In the Empire boats of the "Cabot" class, Graviner equipment is employed to flush the inside of the shroud and the petrol hose coupling with methyl bromide, thereby rendering any remaining petrol non-inflammable and non-combustible. The origin of the device which has now been adopted for service aircraft is the Graviner safety switch, which was designed and made nearly five years ago by Captain H. M. Salmon, and was used to cut off the ignition and lighting circuits of a motor car should a crash or overturning occur. This was effected by a pendulum which, with sufficient inertia on impact, breaks the contact and makes the ignition and lighting system inoperative.

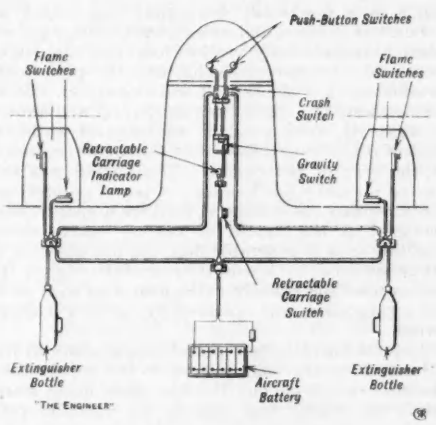


FIG. 1—WIRING DIAGRAM

In applying this device to aircraft the Air Ministry suggested that the device should be so applied that it would automatically operate a fire extinguisher. Moreover, it was laid down that such an apparatus must operate in the event of a crash, or the overturning of the machine, or if fire should break out in the air or on land, while push-button operation by the pilot was also to be possible as a precaution against fire on the pilot seeing that a crash is imminent. The Air Ministry further required that the extinguisher should be automatically operated in less than ten seconds after a deceleration of "6 g" which is the minimum rate of deceleration to cause crash conditions and serious damage to a machine. Tests which were carried out at Farnborough subsequently showed that these requirements were fully met, and ultimately Graviner equipment was fitted experimentally to service machines. The equipment is now being standardised for Royal Air Force machines and Graviner pipes for distribution of methyl bromide fire-extinguishing fluid now form an integral part of the Rolls-Royce, Bristol, Napier and Armstrong-Siddeley aero-engines which are being built for the Royal Air Force.

In the accompanying drawing, Fig. 1, we show a typical wiring diagram for a twin-engined aircraft with two extinguishers. It indicates the relative positions of the push-button switches, the flame switches, the crash switch, and the gravity switch. A further drawing (Fig. 2) shows the arrangement of piping around the engine itself. The extinguisher bottle, which is a solid-drawn copper vessel, containing 6 lb. of methyl bromide gassed with nitrogen to a pressure of 60 lb. per square inch, is mounted on a special bracket placed behind the fireproof bulkhead in the engine nacelle. The fluid is carried to the engine by a ½in. flexible pipe, with bulkhead and other fittings of standard Air Ministry design. The general arrangement of the distribution piping for a cylinder-in-line type of engine such as the Rolls-Royce, is shown in Fig. 2. It will be seen that the fire-extinguishing bottle and bracket are mounted at the back of the fireproof bulkhead. The bracket shown in Figs. 3 and 4 is of deep channel construction. It is mounted so as to discharge in the head-downwards position, although when accidentally inverted in an upturned machine, the internal sliding valve of the type generally common to fire extinguishers ensures that liquid discharge still takes place. The bottle is so designed that it can be easily withdrawn from the bracket for inspection or replacement. The charged bottle weighs 9 lb., and it is held in position by the horn-shaped clip over the top and the clamping wire, which can be instantly released

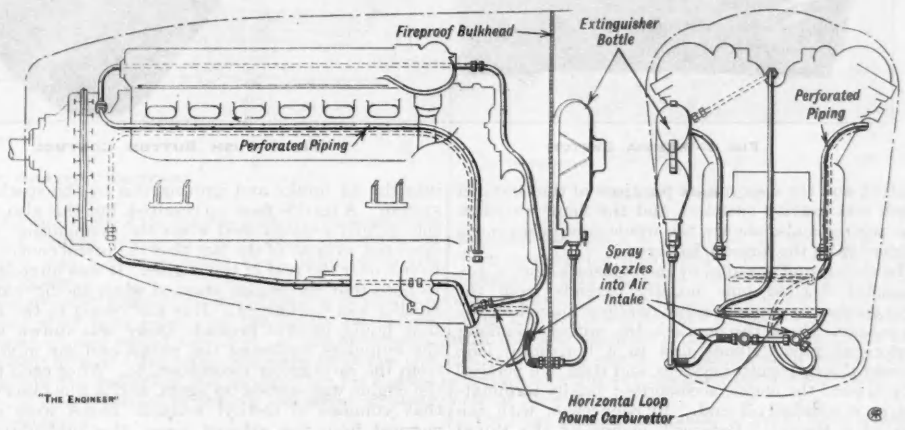


FIG. 2—ARRANGEMENT OF PIPING ROUND ENGINE

by a spring clip. The release of the gassed liquid is effected by an electrically operated fuse and an explosive charge, shown in drawing, Fig. 3, so arranged, that the end stopper in the bottle is blown clear, and arrested by a cross baffle leaving an unrestricted opening for the flow. The arrangement of the plug-in switch is also shown. On some patterns of extinguishing bottle there is an extra outlet nozzle at the side, which is brought into action by the removal of the bottle from the bracket, so that it can be used by the pilot as a hand extinguisher. The extinguishing fluid passes down an ½in. flexible pipe to the air

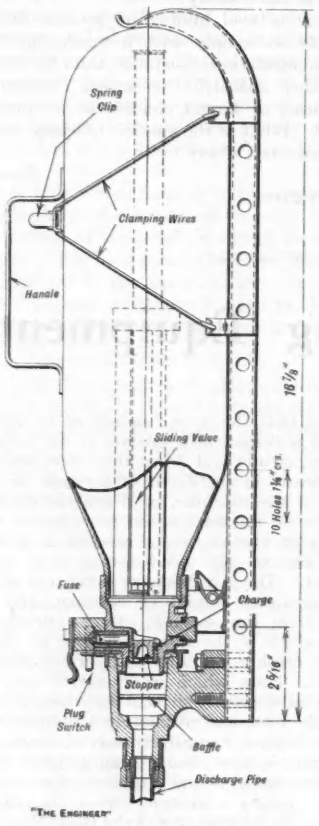


FIG. 3—BOTTLE AND BRACKET

intake from the engine in which a spray nozzle is fitted. It then passes to a Y connection spray nozzle by ½in. diameter 20 S.W.G. piping, and is continued by two perforated pipes of ⅜in. diameter 20 S.W.G. One of these pipes passes centrally below the engine and returns along the exhaust stubs, while the other encircles the carburetter system, rising vertically at the end of the engine, and extending along the front of the engine and back along the other side of the blower casing and the air intake. These pipes have blanked off ends with facilities for cleaning operations and testing. The drawing reproduced in Fig. 1 also indicates the position of the pilot's push-button

sary to find out whether or not corrosion was caused by the injection of methyl bromide into the engine air intake, and its subsequent passage through the engine cylinders and exhaust pipes. For the purpose of this experiment the rear of an engine was enclosed behind the mounting plate by a steel casing, designed to reproduce conditions in the engine nacelle of an aircraft. The extinguisher bottle and bracket were mounted on a wall of the enclosing casing corresponding to a position on the fireproof bulkhead. A ½in. outside diameter plain pipe was taken from the extinguisher bottle to a spray nozzle in the air intake. The spray nozzle was of the banjo type, and had a central removable whirling disc and a single $\frac{1}{16}$in. diameter hole through which a rose type of spray was injected into the air intake. A ½in. outside

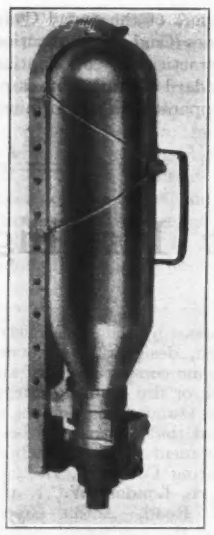


FIG. 4

FIG. 5

diameter perforated pipe extended from the spray nozzle in a practically horizontal loop round the carburetter system and subsequently the pipe was taken in a practically vertical loop over the engine accessories and blower casing, &c., the pipe finally terminating in a blanked off and closed end. Before the fire tests the engine was started up and allowed to warm up, after which it was stopped while two pints of petrol were thrown over the engine accessories at the rear of the engine. The engine was then started up and a fair quantity of petrol pumped into the air intake, this being ignited by a spark system arranged at the mouth of the air intake casing, resulting in a considerable flare up, not alone in the air intake itself, but also at the rear of the engine. The flames were successfully extinguished as soon as the fire extinguisher was operated by pressing a control switch.

In subsequent tests a petrol supply was run from a tank above the engine down to the accessories at the rear of the engine, the fire again being started while the engine was running by injecting petrol

from the methyl bromide liquid spray drawn in with the combustible mixture. The engine, however, started up practically normally after one or two revolutions of the propeller, and no damage appeared to be caused to the engine by repeated discharges of the extinguisher over the engine accessories and in the air intake. Subsequent examination of the engine interior after dismantling showed no signs of corrosion, discolorisation, or other deleterious effects, which is in accordance with expectations, as methyl bromide evaporates when liberated in free air and leaves no trace or deposit. As a result of the tests, the Air Ministry decided to fit air intake nozzles on all installations.

Automatic Switches

Having dealt with the general application of the Graviner system and the effect of methyl bromide as a fire-fighting reagent, we may pass to the automatic switches which form an important part of the equipment. The inertia or crash-operated switch and the gravity switch are shown in Figs. 6 and 8. The multi-contact crash-operated inertia switch is designed to operate as many as six extinguishers, and is capable of being set to release at varying values of "g" the acceleration due to gravity, a normal value of "6 g" being generally adopted by the Air Ministry. As will be seen from the drawing reproduced in Fig. 11, it consists of a small steel pendulum, which on its under face is hollowed out to form a crater, in which a pin mounted at the end of an arm engages. The design is such that the pendulum crater enables the pendulum to remain seated on the pin under conditions of vibration, but any sudden impact corresponding to a deceleration of "6 g" releases the arm causing the spring-controlled spindle to close the contacts, and operate the extinguisher. A small knob on the top of the switch with two positions serves to set the pendulum or to release it for testing purposes.

The gravity switch shown in Figs. 8 and 12 is designed to ensure the automatic discharge of the extinguishers in circumstances where an aircraft inadvertently turns over on its back during landing operations. The switch, as the drawing shows, is operated by a hinged pendulum, which is fitted with a damping device of the toothed sector, pinion, and fly-wheel type. The battery circuit to this particular switch is also supplied over a control switch, such as that for the retractable carriage, the position of which, when down and locked, is indicated by a green light. The switch therefore remains inoperative until the carriage is down and locked, which covers the conditions associated with inverted flying and aerobatics generally. For convenience with regard to electrical connections the crash switch and the gravity switch are placed in adjacent positions. Another interesting switch is the flame and temperature operated switch, shown in Figs. 9 and 10. Again the principle of closing open contacts is maintained, the contacts being held in the open position shown in the drawing by means of a spring-controlled plunger. This is held in position by an upper part comprising a weather-proofed cap with an explosive charge and also a joint which is melted by high temperature. The design adopted is such that in contact with flame or when the surrounding temperature exceeds 140 deg. to 150 deg. Cent. the switch operates within two seconds. The burning of the charge or the temperature joint allows the plunger to rise and to close the contacts, thereby

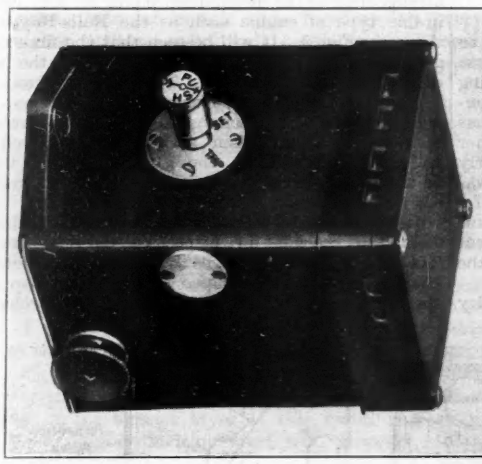


FIG. 6—INERTIA SWITCH

FIG. 7—PUSH-BUTTON CONTROL

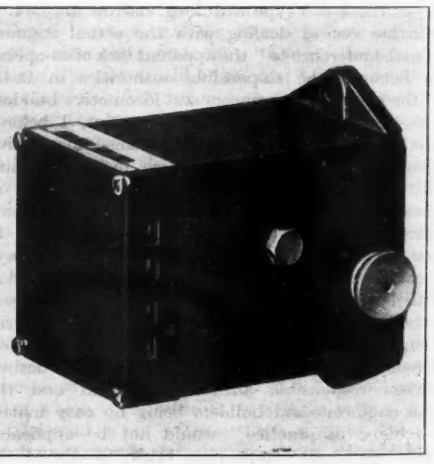


FIG. 8—GRAVITY SWITCH

control, and the appropriate positions of the Graviner crash and gravity switches, and the flame switches. The wiring is also shown, the whole equipment being worked from the aircraft battery.

In the case of a radial cylinder installation, a ½in. diameter flexible pipe usually extends from the extinguisher to a single-spray nozzle arranged on the air intake. From the nozzle a ½in. outside diameter perforated pipe extends first in a horizontal loop around the carburetter system, and then in a vertical loop around the engine accessories; finally terminating in a blanked-off end. In connection with the test of a Bristol "Pegasus" engine at the Royal Aircraft Establishment at Farnborough, it was necessary into the air intake and igniting this by the sparking system. A terrific flare up resulted, but this also was successfully extinguished when the extinguisher was operated, in spite of the fact that the petrol continued to run over the rear of the engine. It was interesting to note that the engine stopped when the fire extinguisher was discharged. This was owing to the fact that liquid methyl bromide spray was drawn into the cylinders rendering the petrol and air mixture from the carburetter incombustible. After each test the engine was started up again, and it was observed that volumes of methyl bromide fumes were discharged from the exhaust pipes, this undoubtedly being due to the evolution of methyl bromide gas causing the extinguisher to discharge. These switches are mounted one at the rear of the engine accessories and the other adjacent to the carburetter system. The position of the switches, which are meant to deal with an uncontrollable flare-up, must be chosen so that they are not exposed to minor air intake flashbacks or are too near to hot engine parts, such as exhaust manifolds. In Fig. 7 we illustrate the push button for use by the pilot or other personnel. It may be noted that it is fitted with a special cover marked in red "Fire Extinguisher," different in design from other switches generally used in an aeroplane. The cover or shield of the switch is furnished with a spring flap, which has to be raised so

as to uncover the button before pressing in order to effect the operation of the extinguisher.

CIVIL AIRCRAFT AND OTHER APPLICATIONS

Only this month it became necessary under Air Ministry regulations to fit fire extinguishers of approved patterns to new passenger-carrying civil aircraft. We are informed that the Graviner apparatus described above is the only fully automatic type of fire-fighting apparatus so approved. While the regulations do not make it compulsory as yet to fit

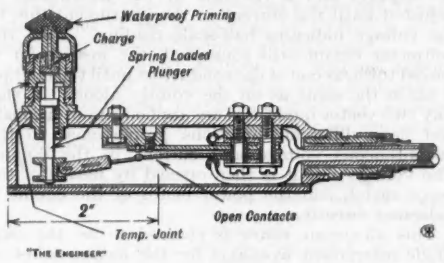


FIG. 9—TEMPERATURE SWITCH

automatic operating fire extinguishers, the cost compared with non-automatic fire extinguishers is but little higher and it is felt that with increasing service experience the fully automatic system will be favoured. For such machines special lay-outs have been devised with the object of simplifying the design and reducing weight as far as possible. In one arrangement a single extinguisher is installed in the cockpit and the pipes are led from a three-way cock to each engine compartment, where perforated piping is used to spray the engines, accessories, and the cowling. The extinguisher is also available for

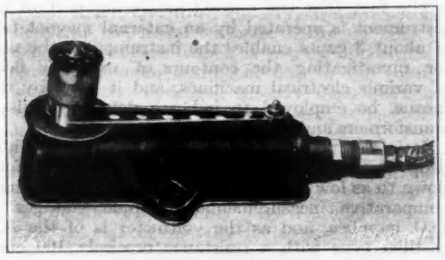
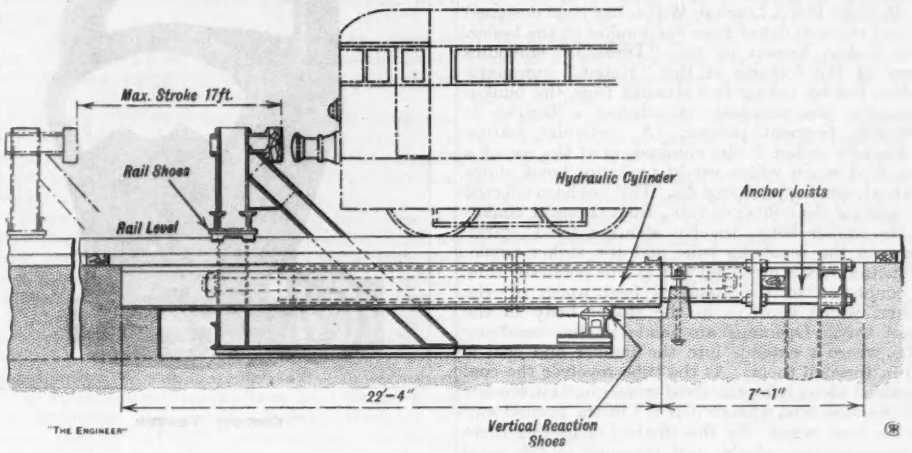


FIG. 10—TEMPERATURE SWITCH

hand use, and crash and gravity switches also push-button switch, are used. Similar equipment is available for all types of power units used in sea craft, such as motor torpedo boats, high-speed tenders, picket boats, motor cruisers, yachts, and petrol barges. For Air Ministry requirements the Graviner Company has also designed two types of hand extinguishers, in 9½-lb. and 3-lb. sizes. We show in Fig. 5 the larger of the two extinguishers. Operation is effected by an easy anti-clockwise turn of the handle, which breaks off a portion of the metal sealing plug used to seal hermetically the extinguisher and causes a finely divided spray of methyl bromide to be delivered from the spray nozzle. A clockwise turn of the handle shuts off the spray and a seal is again made with the portion of the plug not broken off. The bottle can be opened and closed several times. These extinguishers, especially the smaller one, which only has a diameter of 2½in. and a length of 10in. to 11in., can easily be stowed in personnel compartments, wireless compartments, or the passenger accommodation, and used to extinguish small fires, as oil and fuel-wetted material surfaces and petrol-soaked clothing can be rendered non-inflammable by the application of a spray of methyl bromide. In confined spaces it is, however, necessary to shut off the extinguisher as soon as the fire is out in order to avoid the inhalation of irritant methyl bromide fumes.

Hydraulic Buffer

A SERIES of tests was recently carried out at Aldgate East Station by engineers of the London Passenger Transport Board on a new type of hydraulic buffer stop made by Ransomes and Rapier, Ltd., Waterside Works, Ipswich. It is designed for a maximum duty of stopping a 300-ton train moving at a speed of 13 miles an hour. The accompanying diagram shows the general arrangement of the buffer as installed.



ARRANGEMENT OF HYDRAULIC BUFFER

It has a maximum stroke of 17ft. and the resistance, which is practically constant throughout the stroke, is 106 tons. The buffer is built into a shallow pit, 4ft. 10½in. deep by 43ft. 4in. long, and consists of a heavily braced structure, which slides along the track rails at one end, against the resistance of a hydraulic cylinder, vertical reaction being taken by a shoe on the underside of the pit girders. These pit side girders, which are 22ft. 4in. long, resist the upward reaction of the buffer structure on their lower face and serve to carry the track rails over the span of the open pit.

The buffer structure is connected through a swivel joint to the piston-rod, the piston of which works in a hydraulic cylinder of sufficient length to accommodate the full 17ft. stroke. The swivel joint between the buffer structure and the piston-rod relieves any possible bending strains.

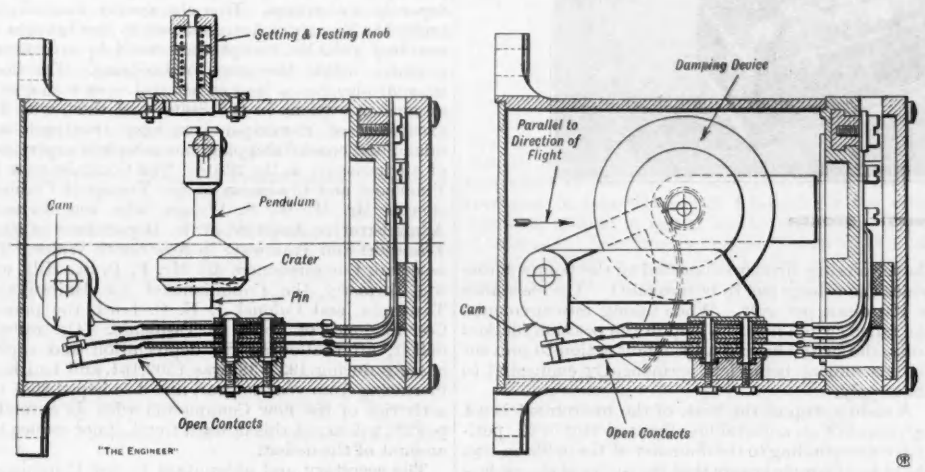
The centre line of the cylinder is 1ft. 10in. below rail level and about 5ft. 4in. below the buffer level, so that considerable overturning effect is experienced by impact by a train. This overturning movement is counteracted by the design of the buffer structure, which has a length of 15ft. between the centres of the upper shoes on the running rail, and the lower ones on the underside of the pit side girders. The structure is well braced and gusseted to avoid distortion on impact, and a timber buffer block is fitted to the cross girder.

The cylinder consists of two lengths of cold-drawn welded steel tube jointed at the centre by flanges screwed on and bolted together. It has an internal diameter of 15in. The tubes are screwed at one end to receive the anchorage and at the other for a gland fitted with a U leather to prevent leakage of oil along the piston-rod.

The cylinder is anchored by four 3in. diameter bolts to a cross girder connected to three vertical joists which are built into the foundation. Grilling is provided below pit level for securing the girders. The cylinder itself is also supported by a saddle and strap and by a cross girder between the two pit side girders and by a strap towards the buffer end.

The piston has two longitudinal rectangular slots, which work over two tapered strips fixed inside the cylinder wall. In this manner the area for the passage of the oil from front to back of the piston is provided throughout the length of the stroke and the areas of the orifices are so designed that the retardation force is constant.

A valve plug and air release cocks are provided on the cylinder for use when filling or replenishing the oil. Shackles are fitted to the buffer structure for the attachment of rope tackle for resetting the buffer after impact. We are informed that, although it is possible to fit this type of equipment with automatic resetting gear, it was not required on this installation.

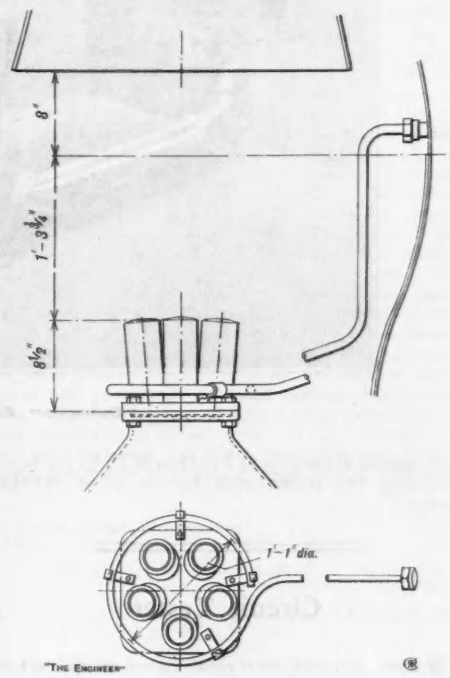


FIGS. 11 AND 12—INERTIA AND GRAVITY SWITCHES

Locomotive Blast Pipe Caps

IN order to improve the steaming qualities of the "Lord Nelson" class engines, Mr. G. V. Bulleid, the Chief Mechanical Engineer of the Southern Railway Company, is fitting them with an improved form of multiple jet type blast pipe caps.

The caps now being fitted are shown in the accompanying drawing. The arrangement consists of five jets, of 3½in. outside diameter, welded in place on the base and inclined 1 in 12. Into the end of each jet there is welded a steel ferrule, which has an inside diameter of 2⅝in. Engines fitted with these jets have larger chimneys than before, the original chimneys being 1ft. 3in. diameter at the choke, as compared with the new diameter of 2ft. 1in. at the choke and 2ft. 8in. at the mouth. A solid drawn copper tube blower with eight ¼in. diameter holes is set round the base of the jets.



BLAST PIPE CAP

The blast pipe tips originally fitted to these engines had a 5½in. diameter orifice, whilst the five nozzles

now fitted have a cross-sectional area some 13 per cent. greater.

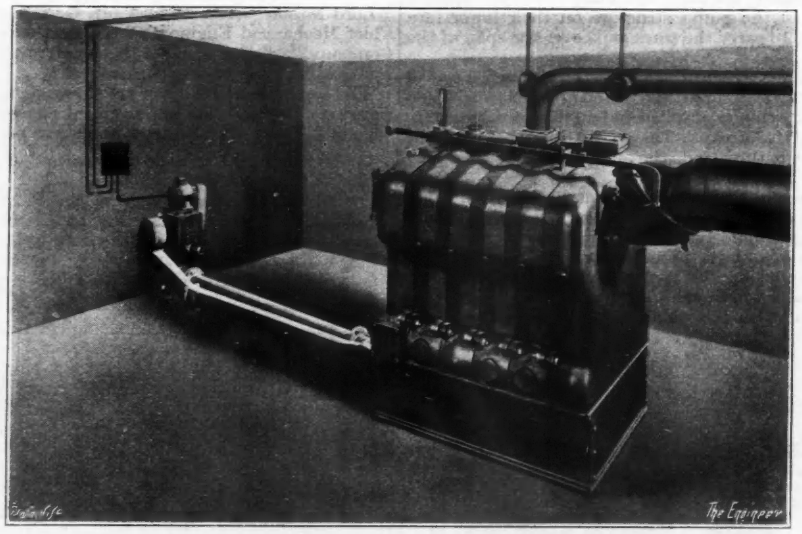
The greater entraining action of the number of jets of steam gives an increased smoke-box vacuum, although the back pressure in the cylinders is reduced, as a result of the increased blast pipe area, and the velocity of the chimney discharge is decreased, owing to its larger diameter.

A New Automatic Stoker

A RECENT addition to the range of automatic stokers made by the Riley Stoker Company, Ltd., 19, Woburn Place, London, W.C.1, has been designed to feed the coal direct from the bunker to the boiler. This stoker, known as the "Direkto," embodies many of the features of the "Robot" automatic stoker, but by taking fuel straight from the bunker eliminates the necessity of refilling a hopper at relatively frequent periods. A particular feature of the new stoker is the elimination of the use of a long feed worm which would probably break down the coal, causing jamming, &c. This has been effected by making the conveyor tube, from the coal bunker to the stoker body, revolve about a fixed spiral. Between the revolving tube and the stoker tuyère a junction box is arranged and at this point the tube is connected to the standard feed worm of the stoker, which revolves in the stoker body in the usual way. Openings are made in the revolving tube, where it extends into the bunker and coal is fed in through them. As the tube revolves the coal is guided along it by the fixed spirals until it reaches the junction box, whence it is fed in the normal way by the feed worm. By this method of feeding there is no possibility of the coal jamming in the main feed tube and the tendency to break down the coal in the tube is eliminated. There is also perfect synchronisation between the main tube and feed worm, as there is no chance of the tube feeding more fuel than can be taken away by the worm.

The whole unit is driven by a standard "Robot" gear-box with a top-mounted motor arranged near the bunker wall. A typical arrangement of a stoker of this kind is shown in the accompanying engraving.

We are informed that the "Direkto" stoker can be installed in sectional, vertical, and locomotive-type boilers in sizes up to 2 million B.Th.U. per hour, providing the boiler-house lay-out is of suitable design.



"DIREKTO" AUTOMATIC STOKER

Circuit Tester

A NEW electrical instrument known as the Salford "All Circuit Tester" has been brought to our notice by Salford Electrical Instruments, Ltd., of Pell Works, Silk Street, Salford, 3, Lancs. The instrument will measure, without breaking the circuit, voltage, current and power factor, and by calculation power and reactive V.A. may be obtained in a few seconds. It may also be used to measure A.C. magnetic fields, for the detection of faulty windings, and for the measurement of A.C. ripple on D.C. supplies. With certain small accessories its range may be extended to give full-scale reading for 100 millivolts and 1 ampere A.C.

The instrument comprises an open-core transformer with the limbs projecting at the back so that they may be placed astride of the current-carrying conductor. A secondary winding provides the very small current necessary to operate the high-grade indicator through a full-wave metal rectifier. The moving element and rectifier are fed through series resistances in the usual way. Current, voltage and power factor ranges are chosen by means of a small switch on the front of the instrument. For power factor measurements, an additional winding on the transformer, which is normally open circuited, is placed in series with the voltmeter winding by means of a range switch and the vector sum of the magnetic fluxes due to the current and voltage enables the instrument when operated in accordance with instructions to indicate single or three-phase power factor, and hence power and reactive V.A. The accuracy for voltage measurements is claimed to be ±1 per cent., for current ±2 per cent., for power factor from 0·4 to unity ±2 per cent., and from 0·1 to 0·4 ±3 per cent.

CIRCUIT TESTER

Three sockets appropriately engraved are provided at the top of the instrument for the two voltage ranges 0/250 and 0/500. By means of 6ft. leads, the sockets are directly connected to the points across which the voltage has to be measured. The resistance is 100 ohms per volt. When taking measurements, the range switch must be held in the position marked volts, the switch having a spring-off action to prevent the instrument being left permanently connected to the supply.

A sliding stop at the back of the instrument is set by means of an adjustable calibrated arm in the position corresponding to the diameter of the cable in use, the object being to ensure that the centre of the cable is always approximately in the same position with regard to the instrument, irrespective of its diameter. The open core projecting at the back of the instrument is then placed astride the conductor and the reading is taken.

The four standard current ranges are 10, 20, 100, and 200 amperes. With a standard instrument it is also possible to take approximate readings of much larger currents.

As when measuring current the instrument is essentially a flux-measuring instrument and is completely insulated, having no external connections of any kind, it may be used on circuits of any voltage, and in the case of bare conductors the only limit is the distance to which the conductor may safely be approached. Standard instruments are suitable for taking current measurements on circuits up to 750 volts, A.C., and an extension handle can be supplied to use the instrument for current measurements on high-tension lines up to 60,000 volts.

Single-phase power factor measurements up to 300 volts involve three measurements: (1) A reading proportional to the voltage, (2) proportional to current, and (3) proportional to a combination of both. The 500-volt pressure circuit is connected to the supply, and a rheostat in the instrument is adjusted until the current in the instrument due to the voltage indicates half-scale reading. With the voltmeter circuit still connected, the instrument is moved towards one of the conductors until the reading is again the same as on the voltage alone. In this way two vector quantities are applied simultaneously and have different directions proportional to the instantaneous voltage and current in the circuit. The voltage circuit is then opened by means of the range switch and the power factor of the circuit is indicated directly.

This all-circuit tester is claimed to be the only single instrument available for the measurement of three-phase power factor. The current is measured in one phase and the voltage across the two outers. No neutral connection is required. The instrument is adjusted to give full-scale reading on voltage alone by means of a rheostat incorporated in it. The middle conductor of the three-phase system is then approached until the instrument reading is a minimum in which position it indicates the power factor. Out-of-balance conditions on the system do not affect the accuracy of the result.

To measure the idle power (sine φ) on single-phase systems, the instrument is operated in the same way as for measuring the power factor on three-phase systems, whilst for measuring the idle power on three-phase systems it is operated as for the measurement of power factor on single-phase systems.

The fact that the current-measuring part of the instrument is operated by an external magnet field of about 3 gauss enables the instrument to be used for investigating the contours of magnetic fields of various electrical machines, and it may, by this means, be employed to indicate defective coils in transformers and other apparatus.

It is also possible to measure the A.C. millivolt drop across such apparatus as switches and fuses down to as low a reading as 100 millivolts; to make comparative measurements of ripple voltages on D.C. supplies, and as the voltmeter is of the A.C. rectifier type with a resistance precisely 100 ohms per volt, it is also possible to determine resistances and capacitances by calculation.

TASMANIAN TRANSPORT

FROM July 1st, 1939, the management and operation of the Tasmanian railways was transferred from the Commissioner for Railways to a newly constituted Transport Commission, comprising a Commissioner for Transport and two associated Commissioners. This body also takes over the control of the registration of motor vehicles, the licensing of drivers, the licensing and control of commercial road transport, and the determination of the road policy, all of which were previously in the hands of separate authorities. This changeover was effected under the Transport Act, 1938, which also brought all ancillary vehicles, except those used in agricultural pursuits, within the scope of licensing. The Commission also has a limited control over commercial aircraft operations in the State, and thus, with the exception of municipal passenger transport and inland and coastal shipping, has complete supervision of all transport in the State. The Commissioner for Transport and Chairman of the Transport Commission is Mr. M. W. S. Wilson, who was formerly Administrative Assistant of the Department of Road Transport and Tramways in New South Wales. The associate Commissioners are Mr. F. P. St. Hill, who was formerly the Commissioner for Railways in Tasmania, and Colonel J. E. C. Lord, the present Commissioner of Police in Tasmania. The railway deficit, after allowing for depreciation and capital charges during 1937–38, was £302,161, and had been increasing from year to year, and it is hoped that the activities of the new Commission with its extended powers will arrest this upward trend, if not reduce the amount of the deficit.

The secretary and accountant to the Commission is Mr. A. K. Reid, formerly the Research Officer of the Department of Road Transport and Tramways in Sydney, and the Commission's offices are in Argyle Street, Hobart. The Act provides for the appointment of a General Manager for Railways, and Mr. C. J. Rollins, who has been Secretary for Railways for a number of years, has been appointed to that office. Other executive appointments made by the Commission include the confirmation of Mr. H. B. Bennett, in his present position as Chief Engineer for Railways, and Mr. A. W. Newton as Administrator of Road Transport, to provide for the administration of the Commission's functions with respect to motor vehicles and the control of commercial road transport.

The Corrosion of Metals*

By OLIVER P. WATTS†

(*Continued from page 194*)

CORROSION OF TYPE IV: CORROSION BY OXYGEN DEPOLARISATION (*continued*)

Evolution of Hydrogen at the Anodic Member of Couples.—Not only is hydrogen deposited on the anodic member of couples consisting of two different metals, but it may be evolved as visible gas from the anode, and at the same time no hydrogen can be seen at the cathodic member of the couple.

In a half-normal solution of sodium sulphate small strips of iron and silver were connected to form a compound cathode, a gradually increased E.M.F. was applied from a platinum anode, and the current recorded.

Time, min.	Current, mil. amp.	Observations.
0	0·2	Current quickly falls, as invisible hydrogen and oxygen polarise the electrodes
2	0·01	Had to raise E.M.F. to maintain current
7	0·05	Stirring near either iron or silver increases current
9	0·35	Gas clings to anode; current falls with time
14	2·0	No gas visible on iron or silver; platinum covered with gas
20	8	No gas seen on silver, but a stream of fine bubbles from iron
25	30	Bubbles cling to silver and slowly escape

Before gas was visible on either the iron or silver, stirring the electrolyte near either caused a marked increase in the current flowing to that electrode, indicating the presence of hydrogen on both the silver and iron. In the early stages of the experiment it was necessary to increase the applied E.M.F. in order to maintain the currents recorded. One can visualise oxygen devouring hydrogen from the iron and silver, and when the oxygen itself becomes depleted at the metal surfaces, hydrogen piles up, causing polarisation (which is merely opposition to deposition of more hydrogen, due to the solution pressure of the hydrogen already deposited), and so an increase in the applied E.M.F. is needed to maintain the current at its former value.

For the couples iron-silver, cadmium-tin, and iron-arsenic in half-normal sulphuric acid, mere immersion was sufficient to cause evolution of hydrogen gas at the anodic member only. By a proper choice of electrolyte and of metals, it is possible to have visible evolution of hydrogen occur at either the anodic or cathodic member of couples.

If hydrogen displaced from electrolytes in the corrosion of metals by the process of oxygen depolarisation is deposited on anodic in addition to cathodic areas, contact with a cathodic metal or the presence in metals of noble impurities cannot be necessary for corrosion, however much their presence may increase the rate of corrosion in those special cases, where contact with them either increases the total surface on which hydrogen is deposited, or adds to the slow process of oxygen depolarisation the far more rapid type III, corrosion by visible displacement of hydrogen.

Corrosion by Displacement of Cations Other Than Hydrogen.—Faraday's law holds true regardless of whether anode, cathode, or both consist of the purest metals yet obtained, or of a combination of two different metals. No alteration in composition of anode or cathode alters the equality of the totals of anodic and cathodic chemical changes. Putting graphite or platinum in contact with the purest zinc or iron does not permit either of these metals to dissolve, except by displacing its chemical equivalent in a metal or hydrogen, or by producing a lowering in valence of some metal already in the electrolyte equivalent to the metal dissolved.

TABLE II.—*The Corrosion of Metallic Couples in Several Electrolytes*

Couple.	Electrolyte.	Time.	At anode.	At cathode.
		Sec.		
Fe-Ag	50 g. $CuSO_4$/L	3	Cu, plate	Cu plate
Zn-Ag	Ditto	½	Cu, dark	No action seen
Zn-Ag	Ditto	1	Cu, dark	Cu plate
Zn-Fe	Ag plating bath	½	Ag plate	No action seen
Zn-Fe	Ditto	5	Ag plate	Ag barely visible
Zn-Fe	Gold plating bath	5	Darkened	No action visible
Zn-Fe	Ditto	15	Gold deposit	Trace of gold
Zn-Ag	Ditto	5	Darkened	Trace of gold on edge
Zn-Ag	Ditto	20	Gold plate	Gold plate

Pure Metals versus Galvanic Couples in Corrosion.—Corrosion of metals and flow of electric current are frequently associated phenomena. Many metals can be made to corrode by passing current from them into suitable electrolytes. From these circumstances the majority of students of corrosion appear to have concluded that flow of current is always the cause of corrosion, and that corrosion is never the cause of the associated electric current—and this in spite of the thousands of dry cells in daily use in which corrosion of the zinc is the source of the energy represented in the flow of current.

This misconception of the cause-and-effect relation between current and corrosion has resulted in a belief, quite generally held, that a difference in potential between points on the metal surface, or between the metal and some other electrical conductor in contact with it, is a necessary prerequisite to corrosion.

"According to the electrolytic theory, which I am not defending, but simply assuming for purposes of illustration, there can be no corrosion except as there is a difference of potential between two parts of the surface, due either to an initial difference in composition, in physical condition, or in the surrounding mediums.[7]

"An essential condition for the setting up of electro-chemical corrosion is some departure from uniformity."[8]

"It now seems justified to express the opinion that an absolutely pure metal possessing an absolutely homogenous surface would not be dissolved by acids."[9]

There are a few dissenting voices raised in opposition to this chorus acclaiming the necessity for impurities in metals or formation of a galvanic couple by contact with another metal, or by other means, as a prerequisite to corrosion:

"Since differences of homogeneity will tend to cause local voltaic cells and will therefore tend to cause corrosion the natural corollary is that the most homogeneous metal will corrode least rapidly if other things are equal. This is absolutely sound; but some people then assumed, perhaps unconsciously, that other things are equal and that therefore the most homogeneous metal will corrode the least rapidly. This assumption is quite unwarranted by the facts, and yet people have gone farther than this, Bengough and Stuart (*Journal*, Institute of Metals, page 28, 54 [1922]), declaring that, according to the electrolytic theory of corrosion, an ideally pure and homogeneous metal is assumed to be incorrodible. While some reckless upholders of the electrolytic theory of corrosion have said things like this, no chemist would claim that a pure and theoretically uniform piece of sodium would not be attacked by water. In like manner, every chemist would admit that copper would be corroded by concentrated nitric acid containing nitrous acid, regardless of how pure or uniform the copper was."[10]

"The corrosion occurring when dissimilar materials are in contact, is often spoken of as 'galvanic action.' This is generally due to the popular, but erroneous conception that the electric current, existing under conditions of galvanic action, causes the corrosion. As a matter of fact, the current is the result of the corrosion taking place."[11]

So far as the author has observed, this common belief that the corrosion of metals is due to galvanic couples has its origin in the behaviour of zinc in non-oxidising acids. It is seen from Table I (*ante*) that the potential of zinc exceeds the discharge potential of hydrogen on every metal listed, except for amalgamated zinc. The very slow attack of c.p. zinc by dilute sulphuric acid shows that the discharge potential of hydrogen on zinc from the acid is practically equal to the potential of the metal. It follows from this that removal of iron, graphite, &c., from commercial zinc must lessen the rate of attack by non-oxidising acids. From this circumstance it has rashly been concluded that removal of impurities from other metals will have a similar effect on their corrosion, and that, if all impurities could be removed, and differences of potential due to differences in concentration of the electrolyte, of oxygen dissolved in it, and all other causes of non-uniformity be excluded, all corrosion of metal must cease.

Unfortunately for this belief, the behaviour of zinc as the more noble impurities in it are removed, cannot be duplicated for most other metals. Also, this effect of removal of impurities on the rate of corrosion of type III is not followed for the same specimen of zinc in regard to the other three types of corrosion. In corrosion of type I, removal of noble impurities from a metal would seem to be able to reduce the rate of corrosion only to the extent by which such removal might lessen the surface of the specimen which is exposed to the electrolyte.

The instant deposition of copper all over a piece of iron or steel immersed in a solution of copper sulphate indicates that this action is independent of any impurities which may be present, and that the pre-existence of galvanic couples in the metal itself is entirely unnecessary for corrosion of type II. In regard to type IV, it has been shown that for two metals in contact deposition of hydrogen and depolarisation by oxygen dissolved in the electrolyte occur at the surface of the anodic metal, in addition to taking place at the cathodic or more noble member of the couple. Here, too, the presence of noble impurities in the metal is unnecessary in order that corrosion may occur.

Only when the corrosion of a metal is entirely of type III can the breaking of contact with a nobler metal or removal of all nobler impurities in the metal itself, possibly stop corrosion in electrolytes open to the air. Corrosion of types I, II, and IV, if they were occurring, will continue in spite of removal of all impurities from the metal, and of differences in temperature, concentration, &c., from the electrolyte.

In so far as corrosion of type IV is concerned, the author believes that hydrogen is displaced on the anodic as well as on the cathodic member of galvanic couples, and that a unit of surface on the anodic metal contributes to oxygen depolarisation quite as effectively as does an equal area on the cathodic member of the couple. To avoid misunderstanding of terms, the author would call attention to the distinction between the mere deposition or displacement of hydrogen on a metal, and the continuation of this process until the surfaces of contact of metal and electrolyte become so saturated with hydrogen that this is evolved as visible gas.

TABLE III.—*Corrosion of Iron and Iron Couples in Normal Sodium Chloride*

	Cathode, per cent.	Loss.	Variation.
Experiment 1:			
Fe	0	0·0161	−5·8%
Fe-Cu	25	0·0170	−0·6
Fe-Cu	50	0·0174	+1·7
Fe-Cu	75	0·0180	+5·2
	Average	0·0171	
Experiment 2:			
Fe	0	0·0150	−5·9%
Fe-Ag	25	0·0175	+2·9
Fe-Ag	50·3	0·0175	+2·9
Fe-Ag	75·3	0·0169	−0·6
	Average	0·0170	
Experiment 3:			
Fe	0	0·0173	+0·6
Fe-Cu	25·4	0·0160	−7·0
Fe-Cu	49·2	0·0175	+1·7
Fe-Cu	71·5	0·0180	+4·6
	Average	0·0172	
Experiment 4:			
Fe	0	0·0107	−6·1
Fe-Cu	25	0·0117	+2·6
Fe-Cu	50	0·0114	0·0
Fe-Cu	74	0·0119	+4·4
		0·0114	

The Effect on Corrosion of Varying the Extent of Cathodic Surface.—Weighed specimens of Armco iron, alone and coupled with copper or silver, were suspended vertically in beakers in 700 c.c. of a normal solution of sodium chloride in a covered thermostat at 30 deg. Cent. and the loss in weight determined. The total metal surface was kept constant (25·4 square centimetres), but the area of the cathodic member was increased from zero to 75 per cent. of the total surface. The surface of the electrolyte exposed to the air was 71 square centimetres. Specimens were polished, and the narrow extension strips by which electrical contact was made were carefully covered with wax. The upper edge of the uncoated metal was 2 cm. below the surface of the solution. The duration of each experiment was two days, except for the last, which was continued for ten days. The results are given in Table III, in which "per cent. of cathode area" gives the percentage of total surface supplied by the cathodic member of the couple, regardless of any impurities in either metal. Under "variation" is the percentage by which the corrosion of each specimen differs from the average loss in weight of all anodic metals in that particular experiment.

TABLE IV.—*Corrosion of Metals and Couples in Normal Sulphuric Acid*

Cathode area, per cent.	0	12·5	25	50	75	87·5	
Experiment 1:							
Cu-Pt, grammes	0·0819	0·0826	0·0831	0·0791	0·0791	0·0769	Average 0·0799
Variation, per cent.	+2·5	−4·6	+3·7	+4·0	−1·0	−3·8	
Experiment 2:							
Cu-Pt, grammes	0·0769	0·0756	0·0800	0·0759	0·0770	0·0769	Average 0·0770
Variation, per cent.	−0·1	−1·8	+3·9	−1·7	0·0	−0·4	
Experiment 3:							
Cu-Ag, grammes	0·0492	—	0·0472	0·487	0·0590	—	Average 0·0510
Variation, per cent.	−3·5	—	−7·5	−4·5	+15·7	—	

In Table IV are the results of similar experiments with copper alone, and coupled with platinum or silver in normal sulphuric acid for ten days. The surface of electrolyte exposed to the air was 33 square centimetres as in the preceding set of experiments of Table III. All specimens were roughened by fine emery paper. The copper-platinum combination tells the same story as did the iron-copper and iron-silver couples in sodium chloride—considerable

* *Bulletin of the University of Wisconsin.*

† Associate Professor Emeritus in Chemical Engineering.

[7] W. Blum, "Tr.," Electrochem. S., Vol. 52, page 432, 1937.

[8] U. R. Evans, "The Corrosion of Metals," page 68, 1924.

[9] W. Palmaer, "The Corrosion of Metals," Vol. II, page 194, 1931.

[10] W. D. Bancroft, Ind. Eng. Chem., page 17, 337, 1925.

[11] F. N. Speller, "Corrosion," page 189, ed. of 1935.

variation in corrosion, but no indication that the amount of corrosion depends on the extent of surface of the cathodic member of the couple.

Even if it be conceded that all of the 0·15 per cent. of foreign matter in Armco iron is cathodic to iron, there has been a 750-fold variation in cathodic areas in the experiments of Table III, resulting in a deviation of but 7 per cent. from the average corrosion in any experiment.

If hydrogen were really deposited only on the cathodic or more noble member of galvanic couples, and hence depolarisation confined to this member, such tremendous increase of cathodic surface must have resulted in greatly increased corrosion, with the increase definitely related to the area of the cathodic surfaces. Pieces of sheet copper, 1in. by 2in. in dimensions, area 25·8 square centimetres, were placed each in a separate vessel in 150 c.c. of normal sulphuric acid and allowed to corrode under the conditions of the experiments of Tables II and III. The losses were 0·0664, 0·0583, 0·0561, and 0·0551 grammes. Deviations from the average are +12·3, −1·3, −5·1, and −6·1 per cent., comparable to the variations with galvanic couples.

Chemical Depolarisers

For the couple copper-platinum spaced 2 cm., addition of 1 gramme of chromic acid, a powerful depolariser for hydrogen, increased the rate of corrosion in 200 c.c. of half-normal sulphuric acid about 700-fold, and raised the corrosion by depolarisation at the anode from 48 per cent. to 78 per cent. of the total corrosion. For the couple nickel-platinum spaced 1 cm., addition of 3 c.c. of 3 per cent. hydrogen peroxide to 150 c.c. of half-normal sulphuric acid greatly increased corrosion and raised depolarisation at the anode from 72 to 93 per cent. of the total corrosion.

Effect of Distance Between Couples

"With Cambridge water the distance through which copper was effective as additional depolarising surface was 0·75 c., while in 0·001 normal sodium chloride the limit was not reached at 6·35 cm. Depolarisation of hydrogen on the steel surface is limited by the rate at which oxygen can diffuse through the liquid to that surface. Hydrogen is deposited also on the adjacent copper surface, where it can be oxidised just as fast as oxygen is supplied, *i.e.*, just as rapidly as on the same area of steel surface."[12]

That the effects of a galvanic couple can extend much farther than this in electrolytes of good conductivity is attested by the stripping of the galvanising from the mooring chain of the monel metal yacht "Sea Call" for a distance of 6ft. under water. Because of the overhanging bow, this seems to indicate a galvanic effect for a distance of at least 8ft. to 10ft. in sea water.

In a cylindrical vessel, 21 cm. in diameter, with 346 square centimetres of liquid surface exposed to the air, two standard copper electrodes, total surface 4 square inches, were placed on opposite sides of an iron electrode at distances of 2 cm. and 12 cm. in a solution of sodium chloride, 100 grammes per litre, and the current to each copper was read. For a half hour the currents to the two cathodes were practically the same, falling from 0·37 to 0·20 milliamperes in that time. The sixfold increase in distance reduced depolarisation to 57 per cent. of that with the shorter distance between electrodes.

Effect of Depth of Immersion

In separate 2-litre cylinders with an air-electrolyte surface of 40 square centimetres and a total metal surface of 37 square centimetres, standard specimens of copper were immersed at depths of 4·5 cm. and 43·5 cm. Deep immersion cut corrosion to about 65 per cent. of that at shallow immersion, but with rather a wide variation for identical specimens.

Effect of Resistance of the Circuit

In corrosion by oxygen depolarisation the controlling factor is supposed to be the rate at which oxygen, by diffusion through the electrolyte, reaches the metal surfaces on which hydrogen has been displaced by corrosion of the metal. The rate of chemical combination of oxygen with hydrogen, and the resistance of the common acids and salts are held to be of secondary importance as factors in determining the velocity of corrosion in still solutions.

With electrodes of iron and copper 4 cm. apart in a sodium chloride solution, 100 grammes per litre, insertion in the circuit of 10 ohms had no readable effect on the current; 100 ohms reduced the current from 1·5 to 1·4 milliamperes, 1000 ohms to 0·80, and 10,000 ohms to 0·03 milliamperes. It is evident that the resistance, 9 ohms, initially introduced into the circuit by the milliammeter, could have had no significant effect on the current or rate of corrosion.

Effect of Increase in Surface of Anodic and of Cathodic Metal

Corrosion of copper alone, and in contact with platinum at a spacing of 1 cm. in half-normal sodium chloride for ten days, with an air-electrolyte surface of 33 square centimetres, was as follows:—

	Metal surface.	Corrosion.	Increase in corrosion.	
Cu	12·5 sq. cm.	0·085 g.	—	—
Cu-Cu	25	0·105	0·020	24%
Cu-Pt	25	0·139	0·054	39%
Cu-2 Pt... ...	37·5	0·147	0·063	74%

The effect of the limited supply of oxygen is seen in the failure of corrosion to increase in proportion with the increase in total metal surface.

Differences in Oxygen Concentration

A two-compartment cell was made by inserting a diaphragm of parchment, electrodes were put in place, the cell filled with air-free, half-normal sodium chloride solution, and the electrolyte on one side of the diaphragm covered with a layer of melted paraffin. The diaphragm had previously been paraffined for an inch above and below the intended water line.

Two iron-platinum couples had been inserted with electrodes reversed, so that the iron of one couple and the platinum of the other was in the electrolyte of high oxygen content. In thirty-three days the loss of weight of iron was 0·096 grammes, when this electrode was in the electrolyte of low oxygen content, *versus* a loss of 0·061 grammes for the iron of the other couple. Depolarisation at the platinum contributed more to corrosion than did depolarisation at the iron. The loss in weight of one iron is 64 per cent. of that of the other.

Conclusions

If corrosion is electro-chemical in nature, as now generally believed, it should be possible to slow down or even prevent corrosion by suppressing either the anodic or cathodic half of the complete electro-chemical reaction. Examples of restriction of corrosion at the anode are seen in the corrosion of lead by dilute sulphuric acid, of silver by hydrochloric acid, and in the passivity of iron. Partial suppression at the cathodic end of the reaction is seen in the effects of inhibitors on the corrosion of iron in dilute sulphuric acid, and of amalgamation on the rate of corrosion of commercial zinc by dilute sulphuric or hydrochloric acid.

Chromium plate owes its permanent brilliance under atmospheric exposure to a protective film formed by incipient oxidation of the metal. Aluminium is far more active chemically than iron, zinc, or even chromium, and is capable of decomposing water when really in contact with it. Most of the present uses of aluminium are possible only because of the adherent and durable film of oxide which covers it. The real chemical activity of aluminium and chromium is shown when these metals are placed in concentrated hydrochloric acid, which is capable of dissolving the protective oxide films. Chromium plate is quickly dissolved and the corrosion of aluminium is not merely rapid, but violent. Silicon is another active element that owes its stability in contact with the atmosphere and moisture to a film of oxide on its surface. This ability of chromium and silicon to form protective films is utilised in the corrosion-resistant alloys, stainless steel, and "duriron."

The vigorous corrosion of copper and silver by strong nitric acid, in contrast to their very slow corrosion in sulphuric acid of equivalent strength, is due to the fact that the former is both an acid and a powerful oxidising agent—a depolariser for hydrogen.

Since, in the corrosion of galvanic couples consisting of two different metals in contact in an electrolyte, the displaced metal or hydrogen is deposited on the anodic metal itself, in addition to being deposited on the cathodic member of the couple, cathodic impurities in metals are entirely unnecessary to corrosion, however much their presence accelerates corrosion in certain special cases.

All that a metal needs in order that it may corrode is the presence in the electrolyte of either hydrogen ions or some metal ions which it is able to displace from solution. Grant this, and corrosion occurs; deny it, and (except for type I) corrosion cannot take place in a day, a year, or a century.

[12] W. G. Whitman and R. P. Russell, Ind. Eng. Chem., V. 16, 278, 1924.

BRITISH STANDARDS INSTITUTION

All British Standard Specifications can be obtained from the Publications Department of the Institution at 28, Victoria Street, London, S.W.1. The price of each specification is 2s. 2d. post free, unless otherwise stated.

DIAL GAUGES, DRAFT SPECIFICATION.

The British Standards Institution is now issuing a draft specification for dial gauges, which has been prepared in response to a request from the Institution of Production Engineers and forms one of a series for engineers' precision tools. Its main purpose is to set up a standard of accuracy for the commoner types of dial gauges. For the most part, these gauges have fairly long ranges of movement, and the accuracies attainable in their manufacture are not so high as might be achieved with more restricted movements. It is proposed to investigate the possibility of laying down accuracies of a somewhat higher order, which would be applicable to shorter range dial gauges. The specification applies to gauges with dials 1½in. to 2in. of 0·001in., 0·0005in., 0·0001in., and 0·01 mm. As an example of the tolerances recommended, we give those for a dial 1½in. to 1¾in. diameter, with a magnification factor of 39–43 and one hundred divisions of 0·001in.:—

Interval of reading.	Possible error over interval stated, inches.
Any 0·01in.	0·0004
Any half revolution	0·0005
Any one revolution	0·0006
Any two revolutions	0·0008
Any larger interval	0·0001

There are in all five similar tables for types of gauges, the larger the magnification factor the smaller the permissible errors. Amongst three appendices one is devoted to the care and use of dial gauges and another to size, calibration, &c.

This specification is sent out in its present draft form, as is now customary with the Institution, in order that the views of makers and users may be obtained before it is printed in its final form. Readers who may feel an interest in the subject are advised to approach the B.S.I., at 28, Victoria Street, S.W.1.

WROUGHT IRON FOR GENERAL ENGINEERING PURPOSES; "BEST YORKSHIRE" WROUGHT IRON.

No. 51—1939; No. 858—1939. There has for many years been in existence a British Standard for wrought iron for use for railway purposes. In order that the usefulness of the specification might be increased, it has recently been revised and the scope extended to cover wrought iron for general engineering purposes. In effecting this revision it was thought desirable to issue the requirements for "Best Yorkshire" iron in a separate publication, and it has now been made the subject of B.S. 858—1939. B.S. 51 now includes the three grades only, namely, A, B, and C. The mechanical properties have not been altered, but the opportunity has been taken to remodel the wording of the clauses with a view to removing a number of ambiguities. The specifications in their present form will be far more serviceable to engineers and industry as a whole.

FRACTIONAL HORSE-POWER ELECTRIC MOTORS AND GENERATORS

No. 170.—This specification has now been revised and extended to include generators as well as motors. The new edition includes several features which were not covered at all in the 1926 edition. These new features may be summarised as follows:—(*a*) Motors of the "universal" type are now included; (*b*) provision for short-time rating, as well as continuous rating; (*c*) recommended horse-powers and speeds. One effect of these new features is that motors intended for use with domestic electrical refrigerators are included within the scope of the specification.

DISTRIBUTION BOARDS

No. 214—1939. The new edition of this specification covers a considerably wider field than the 1929 edition, since it includes phase-splitting distribution boards, circuit-breakerdi stribution boards, and switch and fuse distribution boards. It also covers boards up to 100 amperes per outgoing circuit operating on voltages that do not exceed 250 volts to earth. Metal-cased boards, whether of cast or fabricated construction, are specified in detail and weatherproof requirements are given. Wood-cased boards and boards with glass fronts are also included and the specification lays down the minimum dimensions of wood and weights of glass which shall be used to provide adequate mechanical strength. Cases of insulating material are also, for the first time, recognised as standard, and tests for the degree of inflammability are referred to.

VOLTAGE-OPERATED CIRCUIT BREAKERS

No. 842.—This specification deals with voltage-operated air-break, earth-leakage circuit breakers for use on domestic, farm, and factory premises, up to medium voltage and 200 amperes. It was prepared at the request of the Wiring Regulations Committee of the Institution of Electrical Engineers. The specification is divided into two parts—Part I covering the earth-leakage features and Part II the general features, consisting substantially of an extract from the appropriate clauses of the B.S. Specification for Air-break Circuit Breakers. The specification covers rating, sizes of marking, certain features of design and construction, performance, and tests.

FUEL-FIRED FURNACES FOR HEATING AND HEAT TREATMENT

No. 859. This British Standard Code provides for two forms of test, viz.:—

Part 1: A short, simple code for carrying out, at minimum cost, simplified industrial tests for evaluating the performance of furnaces as effective and economic units.

Part 2: A comprehensive code for the complete evaluation of the performance and the efficiency of furnaces.

The Code is applicable to mill and forge furnaces for the continuous and batch heating of ingots, slabs, blooms, and billets and to a wide range of fixed hearth, bogie, and conveyor-type furnaces employed by the iron and steel industry for the reheating and heat treatment of rolled, forged, or cast products. It is also applicable to certain furnaces used in the non-ferrous and other industries. The Committee responsible for drafting this Test Code has endeavoured to make it as comprehensive as possible in regard to its application, and, although various specific types of furnaces are provided for, it must be realised that other types exist and still more will be evolved in the future. The Code may therefore not be applicable to all such furnaces, but, nevertheless, will serve as a guide.

Markets, Notes and News

The prices quoted herein relate to bulk quantities. Unless otherwise specified home trade quotations are delivered f.o.t. Export quotations are f.o.b. steamer. A comprehensive list of the prices of materials mentioned below will be found on the next page.

British Trade with Malaya

The import trade of Malaya is of some importance to the British iron and steel industry, and the Report on Economic and Commercial Conditions in Malaya, published by H.M. Stationery Office, price 2s. 6d. net, contains some useful information. The Report deals with a period ending March, 1939. In the introduction it is pointed out that the prosperity of the country is dependent upon its two major industries, rubber and tin, both of which are at present regulated internationally, and to a lesser extent upon its agricultural products. The position of the United Kingdom in the import trade of Malaya has improved in the smaller total import figures of 1938. In the main this improvement has been at the expense of Japan, which has lost such a large share of her trade through the action of the Chinese community in boycotting goods from Japan on account of the conflict in the Far East. There have been attempts to import Japanese goods as originating in other countries, but they have usually been abortive. On a number of occasions British goods have come under suspicion through malicious rumours. The total trade in iron and steel and manufactures thereof advanced in 1937 and receded slightly in 1938, in which year Great Britain improved her share to 47 per cent. For the past three years the United States had improved her position, but in the case of other countries imports had fluctuated, particularly in the case of Japan, whose imports in 1938 were only a tenth of those of the previous year. In the case of steel bars, rods, angles, shapes, and sections the total imports in 1936 were 34,537 tons; in 1937, 41,278 tons; and in 1938, 27,567 tons. Of these totals, Great Britain sent in 1936 10,012 tons; in 1937, 10,416 tons; and in 1938, 8264 tons. Belgium, however, sent 11,900 tons in 1936, 14,738 tons in 1937, and 11,814 tons in 1938. Great Britain increased her imports of steel plates and sheets in 1938 by 900 tons and by 200,000 dollars in value, although there was a decline in the total trade in this commodity. Last year the imports from Great Britain totalled 6734 tons, Belgium being next with 3875 tons, and France next with 2306 tons. In 1938 the total imports of railway material, including steel rails, tyres, wheels, and axles, dropped to 3960 tons, compared with 7037 tons in the previous year. The British share of this trade was 293 tons, against the German share of 1733 tons. Japan sent 313 tons and France 674 tons.

The Pig Iron Market

New business in the pig iron market has again become quiet and the recent tentative buying by consumers anxious to replenish stocks has completely died down. The market, however, now wears the appearance customary at this time of the year. Holiday "wakes" are taking place in most Northern industrial districts, and this, of course, affects the consumption of pig iron, and in all probability new buying on any scale will not develop in the market until the early autumn. On the North-East Coast most of the consuming works have restarted after the annual stop week, and although their requirements are not large they should be sufficient to reduce the stocks which had accumulated during the time deliveries were suspended. Some of the makers on this coast have been offering parcels for prompt and nearby delivery to their regular customers, but comparatively little business has been secured in this way. Deliveries of Midland irons continue to be made in the Cleveland district, but apparently the local producers are indifferent to this invasion. In the Midland district consumers of high-phosphoric pig iron seem to have retired from the market for the time being and most of them appear to have covered their requirements for the next couple of months. Some makers report that specifications are reaching them on a more liberal scale than for several weeks, but this is not the general experience. The demand for low-phosphoric foundry iron continues active and considerable tonnages are passing into consumption principally by engineering works. The demand for this class of iron has materially reduced the stocks at the blast-furnaces. The makers have also sold a good proportion of their output over the next four months. Prices are uncontrolled and are firm at about £5 12s. 6d. to £6 d/d. In the Lancashire market there is a steady demand from engineering concerns, particularly those engaged upon Government work. The electrical engineering industry also is taking up good quantities, but new business remains slack. The producers of foundry iron in Scotland are obtaining little fresh business, and the dull conditions prevailing in the light castings industry have limited the amount passing into consumption. On the other hand, the production of steel-making iron is at a high level, although there have been large imports of Indian and English basic iron. The market for hematite is satisfactory, considering the time of year, and specifications continue to reach the producing works on a liberal scale. The stocks in the hands of some of the makers are still large, but there has been a considerable reduction since prices came down at the end of June, and it is expected that this process will continue.

Scotland and the North

The reserve of orders on the books of the Scottish Steel Works is increasing, and as a consequence delivery dates are lengthening. The manufacturers are struggling to avoid falling into arrears, but some difficulty in this direction seems inevitable, since consumers are pressing for material due against contracts, and in many instances are trying to accelerate delivery. Production is at a very high level, and it is not easy to satisfy the requirements of consumers. A good proportion of the output is passing to the firms engaged upon rearmament work, but the shipyards are taking heavy tonnages, and the ordinary commercial demand has expanded during recent weeks. After a quiet period so far as new business is concerned, there has been a revival of activity, and since the holidays there has been a good volume of inquiry in the market. The demand from the shipyards for plates and sections has improved, and the works producing this class of material are operating practically at capacity. There seem good prospects that the improvement in the Clyde shipbuilding industry will be maintained, and that still heavier quantities of steel will be needed during the coming months. The structural engineering firms are also well employed, most of them upon Government contracts, and the requirements of joists, angles, and sections absorbs a considerable part of the current output. The marine engineers have a large volume of work in hand, and anticipate securing fresh contracts in the near future. The malleable iron makers are not well off for orders, although their position has improved, as a certain amount of business has been passed to them owing to the difficulty of obtaining the required delivery from the steel works. Few, if any, of the mills, however, are working full time. The Scottish re-rollers are well off for orders, but are handicapped by the shortage of billets and sheet bars, and in some cases are dropping into arrears against contracts. The sheet works also are fully employed upon A.R.P. orders, to which ordinary commercial business has to give priority. In the Lancashire market, new business has been rather quiet, but large tonnages of bars and constructional steel are going into use. The boiler and tank makers are busy and absorbing good quantities of steel. In some instances makers are asking up to fourteen weeks for delivery of bars, 3in. and up. Business in special and alloy steels has increased recently, and most of the works have a good tonnage of orders for these qualities in hand. The works on the North-West Coast are busily occupied, and are likely to maintain their present rate of output until the end of the year.

The Midlands and South Wales

Although holiday conditions prevail in the Midlands, large tonnages of steel of all descriptions continue to pass into consumption. New business, however, is quiet and this is scarcely to be wondered at, considering the heavy contracts into which consumers entered a few weeks ago. Most of the steel works have sufficient orders in hand to keep them operating at the present high rate until the end of the year and in some instances well into 1940. There is some complaint from users of delays in deliveries, but they relate principally to business for which priority cannot be claimed. A feature of the position is also the pressure exercised by many consumers, particularly those engaged upon Government contracts, to obtain accelerated delivery. Quite a number of Midland makers are not in a position to accept fresh orders except for delivery late in the autumn, and this contributes to the rather quiet appearance of the market, so far as new business is concerned. The production of joists, angles, and other classes of structural material is on an enormous scale, and with the constructional engineers engaged upon jobs likely to keep them employed until the end of the year at least, there seems little likelihood of any diminution in output. In spite of the heavy imports of semi-finished steel, users of billets and sheet bars are still short of their full requirements, and this in some cases has administered a check to output. The position, however, has improved over the last few weeks, and assurances are forthcoming that increased supplies will be available for the remainder of this month. This principally affects the re-rolling industry, as many of the British makers are behind hand in their deliveries against contracts. The imports are in any case not sufficient to bridge the gap between British production and consumers' requirements. The re-rollers have enough work on hand to enable them to operate at capacity for some time, if they can rely upon adequate supplies of semis becoming available. A feature of the Midland market is the continued large demand for colliery steel. The managements of the mines are anxious to lay in reserves in case of an emergency, and are providing an exceptionally good outlet for this material, considering the season of the year. In the South Wales market some stringency is experienced in the supply of sheet and tin-plate bars. The producing works operated fifty-four furnaces throughout the holidays and the tin-plate works were able to make a fairly good restart. There is, however, no doubt that the demand is in excess of the supply, and hopes are expressed of increased imports of suitable foreign steel.

Current Business

A contract valued at about £35,000 has been placed with Head, Wrightson and Co., Ltd., Thornaby-on-Tees, for a special type of lift bridge for Eire. The British Thomson-Houston Company, Ltd., has received an order from the Great Western Railway for the conversion of equipment to add to the supply to the electric line between Paddington and Hammersmith. The contract includes five air-cooled steel tank rectifiers of 1500 kW capacity each, with tuned smoothing circuits, associated A.C. and D.C. switchgear, and twelve track feeder equipments. John Brown and Co., Ltd., Clydebank, are to receive from the Admiralty, subject to the settlement of certain details, a contract for the construction of a battleship of the 1939 programme. Patent Retorts, Ltd., London, has taken an order for the erection in South Africa of a battery of four rotary Davidson retorts having a capacity of 120 tons daily, for the South African Torbanite Mining and Refining Company, Ltd. The Brightside Foundry and Engineering Company, Ltd., Sheffield, has received a contract for aluminium rolling mill plant from the Australian Aluminium Company, Pty., of Sydney, including a two-high breaking down mill with tilting tables and three stands of sheet finishing rolls. Workshops in Henry Street and offices and a research department in Summerfield Street, Sheffield, are to be erected for the International Twist Drill and Steel Company, Ltd., Watery Street, Sheffield. Smith and McLean, Ltd., have started up another new sheet mill at Gartcosh to deal with orders for A.R.P. material. Henry Robb, Ltd., Leith, has received orders for two vessels from the General Steam Navigation Company, Ltd. The Chaloner ironstone mine at Guisborough, Yorks, owned by Dorman, Long and Co., Ltd., which had been in operation since 1853, was closed down at the end of last week as it is no longer economical to work the available reserves of ironstone. The Department of Overseas Trade announces that the following contracts are open for tender:—South African Railways and Harbours Administration: Approximately 191 tons of steelwork and 3 tons of bolts, rivets, &c., for bridgework (Johannesburg, August 31st); supply and delivery of one 10,000-gallon capacity pressed steel tank, 20ft. by 20ft. by 4ft. deep, open top (Johannesburg, September 28th). India, North-Western Railways Administration: Supply and delivery of twenty locomotive boilers, superheated for "N" (2–10–0) class non-standard engines (Lahore, September 18th).

Copper and Tin

The copper market has been in a state of nerves arising from the political situation. The most noticeable feature has been the continued heavy purchases of copper by Germany which included rough as well as electrolytic copper. There have also been some withdrawals from warehouse, and since the beginning of the month the stocks in Metal Exchange warehouses have dropped 2637 tons to 25,636 tons from 28,273 tons. The heavy buying of copper by Germany has contributed to the nervous condition of the market, since it is felt that the German Government is accumulating war reserves, and as the greater part of the metal is for delivery by August 31st it looks as though they were in a hurry to build up their stocks. It has been known, however, that for several months the copper-consuming industries in Germany have been hard put to it to obtain supplies, and it is interesting to note that in the first half of this year the German imports of copper were 89,355 metric tons compared with 116,703 tons in the corresponding half of 1938. The effect of these purchases with frequent heavy buying by Japan will certainly affect the statistical position rather sharply, and relief is now expressed that the producers have decided to increase their output as from the middle of August. There have been considerable sales of Rhodesian copper, largely on account of Germany, although some of the metal will come to this country. The standard copper market responded to the buying of electrolytic and the price on Monday rose above £45. It seems likely that there will be a further advance as the prompt position has become distinctly tight. There is a slight backwardation in the market, and although it seems improbable that this will become accentuated, there have been some signs of speculation developing which might falsify this view. . . . Comparatively little interest has been taken in the tin market, and the industrial demand fails to develop any strength. At around the £230 level the Pool continues to sell tin, but it is credited with having 9000 tons to 10,000 tons still in stock. The lethargic condition of the market is indicated by the fact that it is several weeks now since the price has varied to the extent of more than £1. The belief prevails that the tin quotas will be increased at the next meeting of the International Tin Committee. In the United States the demand remains poor, and although it is understood that the consuming industries there have bought directly in the East the opinion persists that stocks are low. A buying movement in this direction would probably have a sharp effect upon prices in this market.

Lead and Spelter

Prices in the lead market have shown a stronger tendency rather on general sentiment than owing to any change in the position. The industrial demand continues, and of late there has been some fresh buying by consumers who wanted to supplement supplies already contracted for. Lead, of course, would be in considerable demand in the event of the worst happening in international politics, and no doubt users have thought it wise to ensure supplies so far as possible. Considerable quantities of lead are going into consumption as a result of the rearmament programme, and there has been some increase in the volume of ordinary commercial orders. It is not expected that the arrivals this month will be on a large scale, and the growing tightness in the prompt position may also afford an inducement for consumers to enter the market. The decline in the building industry continues, and this is an unfavourable feature of the position. Some disappointment is expressed that no lead is being received from Spain, as it was expected that within a reasonable time from the cessation of hostilities in that country supplies would be forthcoming. Shipments from Mexico have also been on a restricted scale of late. As a consequence, deliveries from warehouse in this country have been rather heavy. The American Bureau of Metal Statistics gives the stocks of refined and antimonial lead in the United States on July 31st as 124,017 tons, against 129,366 tons at the end of the previous month. Production during July is given as 37,021 tons, a reduction of 2000 tons, whilst the deliveries increased from 38,701 tons in June to 42,636 tons in July. . . . The spelter market has been featureless, but the tone has remained steady. The arrivals of spelter this month have been on the small side, and as a consequence there have been some deliveries from warehouse. There has, however, been sufficient metal available to meet the market requirements and there is no reason to expect any important upward movement in prices. In the American market the heavy buying in July has been succeeded by a quiet spell. The quantities moving into consumption are apparently satisfactory, and it is reported that the galvanising works are operating at about 61 per cent. of capacity. As in this country, there is a brisk demand for high-grade spelter, of which supplies seem to be rather on the short side. It is reported that Continental metal has been offered in the United States, but the duty payable on metal imported into that country does not make this class of business very profitable.

Current Prices for Metals and Fuels

Makers' official home trade price, per ton, delivered buyers' stations. *Joists, Sections, Bars and Plates are subject to a rebate of 15s. to home users purchasing only from Associated British Steelmakers. †Export prices are for Empire Markets; for other Markets British quotations conform to Cartel prices.

PIG IRON.

Foundry home prices, except for Scotland, less rebate of 5/-. (*D/d Teesside Area.*)

	Home. £ s. d.	Export. £ s. d.
N.E. Coast—		
Hematite Mixed Nos.	5 15 0	—
„ No. 1	5 15 6	5 15 0
Cleveland—		
No. 1	5 2 0	5 2 6
No. 3 G.M.B.	4 19 0	5 0 0
No. 4 Foundry	4 18 0	—
Basic	4 12 6	—
Midlands—		
Staffs— (*Delivered to Black Country Station.*)		
North Staffs Foundry	5 1 0	—
„ „ Forge	4 18 0 to £5 0 0	—
Basic	4 12 6	—
Northampton—		
Foundry No. 3	4 18 6	—
Forge	4 15 6 to £4 17 6	—
Derbyshire—		
No. 3 Foundry	5 1 0	—
Forge	4 18 0 to £5 0 0	—
Scotland—		
Hematite, f.o.t. furnaces	5 15 6	—
No. 1 Foundry, ditto	5 3 0	—
No. 3 Foundry, ditto	5 0 6	—
Basic, d/d	4 12 6	—
N.W. Coast— Hematite Mixed Nos.	5 15 6 d/d Glasgow 6 1 0 „ Sheffield 6 7 0 „ Birmingham	

MANUFACTURED IRON.

	Home. £ s. d.	Export. £ s. d.
Lancs and Yorks—		
Crown Bars	12 5 0	—
Best Bars	12 15 0	—
Midlands—		
Crown Bars	12 5 0	—
Marked Bars (Staffs)	15 15 0	—
No. 3 Quality	10 17 6	—
No. 4 Quality	11 7 6	—
Scotland—		
Crown Bars	12 5 0	12 5 0
Best	12 15 0	12 15 0
N.E. Coast—		
Crown Bars	12 5 0	12 5 0
Best Bars	12 15 0	12 15 0
Double Best Bars	13 5 0	13 5 0
Northern Ireland and Free State—		
Crown Bars, f.o.q.	12 17 6	—

STEEL.

	*Home. £ s. d.	†Export. £ s. d.
London and the South—		
Angles	10 10 6	10 0 0
Tees	11 10 6	11 0 0
Joists	10 10 6	10 0 0
Channels	10 15 6	10 5 0
Rounds, 3in. and up	11 10 6	11 0 0
„ under 3in.	11 17 6‡	11 0 0
Flats, under 5in.	11 17 6‡	11 0 0
Plates, ¾in. (basis)	10 15 6	10 2 6
„ ⅞in.	11 0 6	10 7 6
„ 1in.	11 5 6	10 12 6
„ 1⅛in.	11 10 6	10 17 6
Un. ⅞in. to and incl. 6 lb. per sq. ft. (8-G.)	11 12 6	11 12 6
Boiler Plates, ¾in.	11 13 0	11 12 6
North-East Coast—		
Angles	10 8 0	10 0 0
Tees	11 8 0	11 0 0
Joists	10 8 0	10 0 0
Channels	10 13 0	10 5 0
Rounds, 3in. and up	11 8 0	11 0 0
„ under 3in.	11 15 0‡	11 0 0
Plates, ¾in. (basis)	10 10 6	10 2 6
„ ⅞in.	10 15 6	10 7 6
„ 1in.	11 0 6	10 12 6
„ 1⅛in.	11 5 6	10 17 6
Un. ⅞in. to and incl. 6 lb. per sq. ft. (8-G.)	11 12 6	11 12 6
Boiler Plates, ¾in.	11 8 0	11 12 6
Midlands, and Leeds and District—		
Angles	10 8 0	10 0 0
Tees	11 8 0	11 0 0
Joists	10 8 0	10 0 0
Channels	10 13 0	10 5 0
Rounds, 3in. and up	11 8 0	11 0 0
„ under 3in.	11 16 0‡	11 0 0
Flats, 5in. and under	11 15 0‡	11 0 0
Plates, ¾in. (basis)	10 13 0	10 2 6
„ ⅞in.	10 18 0	10 7 6
„ 1in.	11 3 0	10 12 6
„ 1⅛in.	11 8 0	10 17 6
Un. ⅞in. to and incl. 6 lb. per sq. ft. (8-G.)	11 12 6	11 12 6
Boiler Plates, ¾in.	11 10 6	11 12 6
Glasgow and District—		
Angles	10 8 0	10 0 0
Tees	11 8 0	11 0 0
Joists	10 8 0	10 0 0
Channels	10 13 0	10 5 0
Rounds, 3in. and up	11 8 0	11 0 0
„ under 3in.	11 15 0‡	11 0 0
Flats, 5in. and under	11 15 0‡	11 0 0
Plates, ¾in. (basis)	10 13 0	10 2 6
„ ⅞in.	10 18 0	10 7 6
„ 1in.	11 3 0	10 12 6
„ 1⅛in.	11 8 0	10 17 6
Un. ⅞in. to and incl. 6 lb. per sq. ft. (8-G.)	11 12 6	11 12 6
Boiler Plates, ¾in.	11 8 0	11 12 6
South Wales Area—		
Angles	10 8 0	10 0 0
Tees	11 8 0	11 0 0
Joists	10 8 0	10 0 0
Channels	10 13 0	10 5 0
Rounds, 3in. and up	11 8 0	11 0 0
„ under 3in.	11 15 0‡	11 0 0
Flats, 5in. and under	11 15 0‡	11 0 0
Plates, ¾in. (basis)	10 13 0	10 2 6
„ ⅞in.	10 18 0	10 7 6
„ 1in.	11 3 0	10 12 6
„ 1⅛in.	11 8 0	10 17 6
Un. ⅞in. to and incl. 6 lb. per sq. ft. (8-G.)	11 12 6	11 12 6

	Belfast. £ s. d.	Rest of Ireland. £ s. d.
Ireland—f.o.q.—		
Angles	10 13 0	10 15 6
Tees	11 13 0	11 15 6
Joists	10 13 0	10 15 6
Channels	10 18 0	11 0 6
Rounds, 3in. and up	11 13 0	11 15 6
„ under 3in.	12 0 0‡	12 2 6
Plates, ¾in. (basis)	10 15 6	10 18 0
„ ⅞in.	11 0 6	11 3 0
„ 1in.	10 5 6	11 8 0
„ 1⅛in.	11 12 6	12 10 0
Un. ⅞in. to 1in. incl.	11 12 6	11 12 6

‡ *Rounds and Flats tested quality; untested, 3s. less.*

OTHER STEEL MATERIALS

Sheets.	Home. £ s. d.	Export, f.o.b. £ s. d.
11-G. and 12-G., d/d	13 15 0	11-G. to 14-G. 11 5 0
13-G., d/d	14 2 6	15-G. to 16-G. 11 15 0
14-G. to 20-G., d/d	14 10 0	17-G. to 18-G. 12 0 0
21-G. to 24-G., d/d	14 15 0	19-G. to 20-G. 12 5 0
25-G. and 26-G., d/d	15 10 0	21-G. to 22-G. 12 17 6

South Africa, Rhodesia, Nyasaland, £14; Canada, £14 12s. 6d., f.o.b. basis. Irish Free State, £14 15s., f.o.q., 4-ton lots.

The above home trade sheet prices are for 4-ton lots and over; 2-ton to 4-ton lots, 7s. 6d. per ton extra; and under 2-ton lots to 10-cwt., £2 per ton extra.

Galvanised Corrugated sheets, basis 24-G.—

Home.	£ s. d.
4-ton lots and up	17 5 0
2-ton to 4-ton lots	17 12 6
Under 2 tons	18 17 6

Export: India, £17 15s. c.i.f.; Irish Free State, £17 5s., f.o.q.; General, £15 15s., f.o.b., 24-G. basis.

Tin-plates—

20 by 14 basis, f.o.t., Bristol Channel Ports, 20s. 4½d.

Tin-plate Bars, d/d Welsh Works, £7 5s.

Billets—100-ton lots and over, 35 to 100 tons, 5s. extra; less than 35 tons, 10s. extra.

	£ s. d.
Soft (up to 0·25% C.), untested	7 7 6
„ „ „ tested	7 12 6
Basic (0·33% to 0·41% C.)	7 17 6
„ Medium (0·42% to 0·60% C.)	8 10 0
„ Hard (0·61% to 0·85% C.)	9 0 0
„ „ (0·88% to 0·99% C.)	9 10 0
„ „ (over 0·99% C.)	10 0 0
Rails, Heavy, 500-ton lots, f.o.t.	9 10 0
„ Light, f.o.t.	8 10 0

FERRO ALLOYS.

	Per Ton.	Per Unit.
Tungsten Metal Powder	4/5 per lb.	
Ferro-Tungsten	4/4 per lb.	
Ferro Chrome, 4 p.c. to 6 p.c. carbon	£23 10 0	7/6
„ „ 6 p.c. to 8 p.c.	£23 5 0	7/6
„ „ 8 p.c. to 10 p.c.	£23 5 0	7/6
„ „ Max. 2 p.c. carbon	£36 0 0	11/-
„ „ „ 1 p.c. carbon	£38 5 0	11/-
„ „ „ 0·5 p.c. carbon	£41 0 0	12/-
„ „ „ carbon-free	10d. per lb.	
Metallic Chromium	2/5 per lb.	
Ferro Manganese (loose), 76 p.c.	£16 15 0 home	
„ Silicon, 45 p.c. to 50 p.c.	£12 10 0 scale 5/- p.u.	
„ „ 75 p.c.	£17 0 0 scale 6/- p.u.	
„ Vanadium	14/- per lb.	
„ Molybdenum	4/10 per lb. 5/- forward	
„ Titanium (carbon-free)	9d. per lb.	
Nickel (per ton)	£185 to £190 per ton	
Cobalt	8/6 to 8/9 per lb.	

NON-FERROUS METALS

(*Official Prices, August 23rd.*)

Copper—		
Cash	£44 12 6 to £44 13 9	
Three Months	£44 7 6 to £44 8 9	
Electrolytic	£50 5 0 to £50 15 0	
Best Selected Ingots, d/d Birmingham	£50 10 0	
Sheets, Hot Rolled	£80 0 0	
	Home.	Export.
Tubes, Solid Drawn (basis)	13d.	13d.
„ Brazed (basis)	13d.	13d.
Brass—		
Ingots, 70/30, d/d Birmingham	£40 0 0	
	Home.	Export.
Tubes, Solid Drawn 2/1 Alloy	11¾d.	11¾d.
„ Brazed	13¾d.	13¾d.
Tin—		
Cash	£229 17 6 to £230 0 0	
Three Months	£223 10 0 to £223 15 0	
Spelter—		
Cash	£14 7 6 to £14 10 0	
Three Months	£14 10 0 to £14 11 3	
Lead—		
Cash	£16 2 6 to £16 3 9	
Three Months	£15 17 6 to £16 0 0	
Aluminium Ingots (British)	£94 (net)	

FUELS.

SCOTLAND

Lanarkshire—	Export.
(f.o.b. Grangemouth)—	
Navigation Unscreened	18/- to 19/-
Hamilton Ell	17/6 to 18/-
Splints	20/6
Ayrshire—	
(f.o.b. Ports)—	
Steam	17/6
Fifeshire—	
(f.o.b. Methil or Burntisland)—	
Prime Steam	18/- to 18/6
Unscreened Navigation	18/6 to 19/-
Lothians—	
(f.o.b. Leith)—	
Hartley Prime	18/-
Secondary Steam	17/6

ENGLAND

South Yorkshire, Doncaster—	
Steam Hards	19/- to 20/-
Washed Smalls	16/- to 17/-
Northumberland, Newcastle—	
Blyth Best	19/- to 19/6
„ Second	18/- to 18/6
„ Best Small	15/6
Unscreened	17/- to 18/-
Durham—	
Best Gas	19/9
Foundry Coke	26/- to 28/-

SOUTH WALES

Cardiff—	
Steam Coals:	
Best Admiralty Large	23/6 to 24/-
Best Seconds	23/- to 23/6
Best Dry Large	23/- to 23/6
Ordinaries	23/-
Bunker Smalls	16/- to 17/6
Cargo Smalls	15/- to 15/6
Dry Nuts	27/6 to 28/-
Foundry Coke	35/- to 42/6
Furnace Coke	30/- to 33/6
Patent Fuel	25/6
Swansea—	
Anthracite Coals:	
Best Large	35/- to 38/-
Machine-made Cobbles	38/6 to 42/6
Nuts	40/- to 45/-
Beans	33/- to 40/-
Peas	27/6 to 30/-
Rubbly Culm	15/- to 16/-
Steam Coals:	
Large Ordinary	22/6 to 24/6

FUEL OIL.

Inland consumption: contracts in bulk.

Exclusive of Government tax of 1d. per gallon; and 9d. per gallon on oil for road vehicles.

Ex Ocean Installation—	Per Gallon.
Furnace Oil (0·950 gravity)	3¾d.
Diesel Oil	4¼d.

French Engineering Notes

(From our own Correspondent in Paris)

Railway Rolling Stock

THE long time that has elapsed since orders of any importance were given out for rolling stock is attributed to the serious financial situation of the railways and to the tedious working out of plans for cutting down costs and simplifying and cheapening methods of building locomotives and wagons. A few years ago wagon builders secured the co-operation of a group to finance the distribution of orders over a number of years, but nothing came of the scheme, which could not be entertained when the situation of the companies was rendered precarious by a political movement to transfer all the railways to one State controlled company. So long as this state of things lasted wagon builders suffered severely from a dearth of orders, and some of them were reported recently to be laying themselves out for armament production. Nor was there any appreciable revival of buying after the constitution of the National Railway Company, which was required to prepare a plan for extensive renewals of rolling stock over a long period as soon as arrangements could be made for standardising coaches and wagons and restricting the types of locomotives to be put into service, this being done with the object of accelerating production as well as repairs to locomotives with the aid of strictly interchangeable parts. The preparation of the plan was delayed by pressure put on the company to equip the whole of the railway system with metal coaches. This agitation for greater safety had arisen out of a series of disastrous accidents. A general transformation of rolling stock was out of the question on account of the cost, and the company carried out experiments to show that wooden coaches with steel reinforcement offered as much resistance to shock as all-metal coaches and were cheaper and lighter, while allowing of an economical transformation of existing coaches. The "mixed" type of coach is therefore holding its own for ordinary trains. In November of last year the Government decreed that the S.N.C.F. should prepare a wagon-building programme covering a period of four years from the beginning of 1940. The Chambre Syndicale of wagon builders offered to collaborate with the company in preparing specifications for the new rolling stock. Apparently the plans are nearing completion, for the National Railway Company is now authorised to spend 5000 million francs over a period of five years for the purchase of rolling stock and for carrying out essential construction work. Wagon builders will thus be assured of work under conditions that will allow of economical production. It is time that this was done, for the condition of some of the rolling stock leaves much to be desired and its renewal is long overdue.

Water Supply

Plans for providing the whole country with adequate supplies of water have been carried out within the limits of financial possibilities, which, until the beginning of this year, had seriously declined. The recovery since then released capital that enabled a large number of municipalities to resume undertakings and put in hand new works, with the result that there is much more activity in improving and extending town water supplies. Of equal importance is the provision of water to the 38,000 communes which have, for the most part, to depend upon irregular supplies of water of more or less doubtful purity. The State gives all the assistance it can, both technical and financial, and its services have for several years been investigating the country's subterranean water resources with a view to mapping out a system of distribution; but the work is far from completed, and it is obvious that some parts of the country are much less favoured with these potential supplies than others. A good deal of progress has been made with water distribution in the south-east of France, where rivers taking their rise in the Alps are used for the purpose, and one of them, the Vésubie, is now supplying water to Nice and neighbouring communes. A canal from this river will also serve seven communes at Levans, where a pumping station with ozone equipment will raise water through a main 1¼ miles long to a reservoir 1500ft. above the pumping level. The undertaking is financed in the proportion of 60 per cent. by the State, 33 per cent. by the department, and 7 per cent. by an intercommunal syndicate which is responsible for the work. Another scheme of interest is the utilisation of a small Alpine river for supplying water to nineteen communes in the region of Grasse. The river flows in a valley with a porous stratum through which water percolates, and it is proposed to create a subterranean reservoir by building a concrete wall across the valley down to the lowest depth of the porous stratum. The Compagnie des Eaux et de l'Ozone is prospecting the depth and permeability by sinking steel tubes at different points and subjecting a column of water in each of them to a constant pressure for ten minutes. The difference in water levels in the tubes indicates the degree of permeability. It is hoped to raise 150 litres a second from this subterranean reservoir.

A Novel Dock Gate

The construction dock at Saint-Nazaire built to the design of Monsieur Caquot by the Chantiers de la Loire, and used in common with Penhoët, has fully borne out its promise of saving time in building the largest ships. With the dry dock on one side for the hull, which is floated over to the other side for fitting out, everything is arranged for an economical distribution of work. The South Atlantic liner "Pasteur" recently left the dock, and the 35,000-ton battleship "Jean-Bart" is expected to be floated out before the end of the year. The dock has had a temporary gate pending the construction of one of special form which was placed in position last week. The new gate is of semi-circular form with flanges that bear against the dock posts under the pressure of the water within the dock. It is 147ft. wide and 59ft. high, and weighs about 800 tons. The lower part of the gate is a semi-circular pontoon with water ballast which is pumped out for buoyancy when the gate has to be swung back, and the manœuvring is effected by pumps. The design is novel and the cost was nearly 6 million francs.

British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics.

When an abridgment is not illustrated the Specification is without drawings.

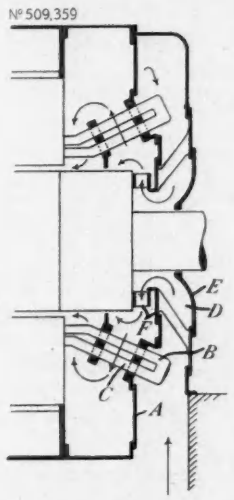
Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery Lane, W.C.2, 1s. each.

The date first given is the date of application; the second date, at the end of the abridgment, is the date of the acceptance of the complete Specification.

DYNAMOS AND MOTORS

509,359. April 19th, 1938.—DYNAMO-ELECTRIC MACHINES, Ernest Barlow, of 166, Walton Road, Sale; and Metropolitan-Vickers Electrical Company, Ltd., of Number One, Kingsway, London, W.C.2.

The object of this invention is to provide improved constructions for the cooling of machines having actually or in effect a fan integral with the rotary member of the machine for causing circulation of cooling air through the ventilating ducts, and in which the windings of the stationary members extend to a comparatively great distance beyond the end of the core. This invention is intended specially for application to enclosed



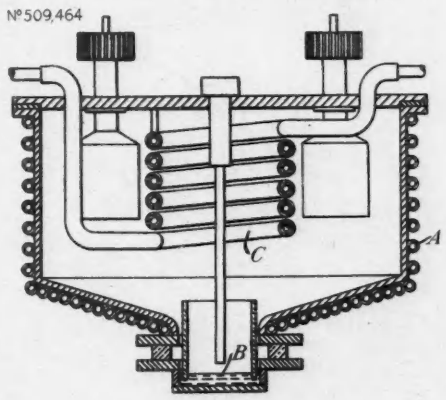
machines with internal self-cooling arrangements, although its use is not limited to machines of this particular character. The machine is provided with an inner casing A pierced to permit the extreme end portions B of the end winding C of the stator to project into the space D which is enclosed by an outer casing E. The space D between the casings A and E forms an intake chamber, through which air passes from the outside of the fan F so that the end portions B of the end windings of the stationary part are cooled by the flow of air prior to its passage through the fan.—*July 14th*, 1939.

TRANSFORMERS AND CONVERTERS

509,464. August 11th, 1938.—VAPOUR ELECTRIC DISCHARGE DEVICES, Westinghouse Electric and Manufacturing Company, of East Pittsburg, Pennsylvania, U.S.A.

The chief object of this invention is to provide an improved cooling system for a vapour electric discharge device wherein the cooling fluid used can be distributed in proportion to the heat exchange desired in the various portions of the container.

The outer surface of the container is substantially covered with a cooling coil A, preferably of copper, nickel, aluminium, or other metal which is substantially impervious to free gases such as are generated by electrolysis of the cooling fluid, these coils being secured in good thermal contact with the container. In these large containers it is frequently desirable to maintain different rates of heat transfer in different sections of the container. For instance, in the region adjacent the cathode B, it is desirable to maintain as low a surface temperature for the

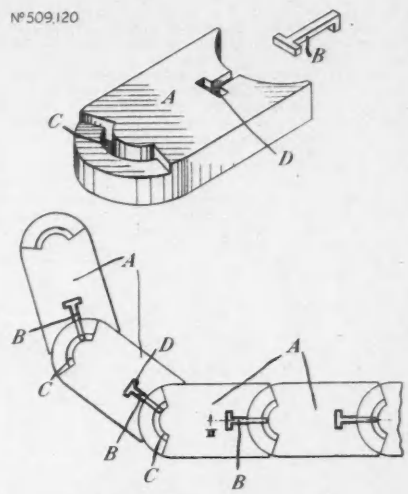


container wall as is possible, but in other sections of the converter a different temperature is sometimes desirable. In order to maintain this condition, the cooling coils A are closely spaced on a portion of the tank where it is desired to maintain a high heat transfer, but on other portions of the tank wall where it is desired to maintain different rates of heat transfer these coils may be spaced apart any suitable distance to maintain various thermal characteristics desired. In the multiple-anode discharge device as shown in the drawing, it is frequently desirable to place internal coolers C usually in the form of a cylinder adjacent to the central portion of the converter. These ring coolers may be constructed of a material such as iron, which is substantially unaffected by the operating vapours of the converter and are also preferably provided with a lining of copper or other gas-impervious material in order to prevent gas leakage as well as to prevent corrosion of the ring coolers.—*July 17th*, 1939.

ELECTRICAL APPLIANCES

509,120. December 1st, 1938.—TILES OR BRICKS FOR COVERING AND PROTECTING ELECTRIC CABLES, Thomas Alec Whitehouse, "Church Farm," Marston, Bedford, and Marston Valley Brick Company, Ltd., Blossoms Inn, 23, Lawrence Lane, London, E.C.2.

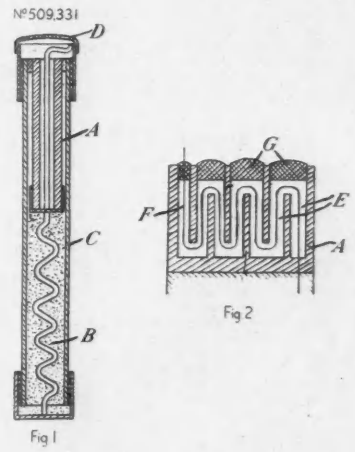
The object of this invention is to provide an improved brick by which, in general, laying is simplified and greater protection is afforded to electric cables. In particular, the bricks may be turned about their interfitting ends through an appreciable angle in the same horizontal plane whilst always snugly fitting together with the avoidance of openings between bricks which might allow stones and earth to fall through and cause damage to the cable when the usual ramming operation is performed after the cable has been laid and covered. The brick comprises an elongated flat strip A, one end of which is convex and the other concave, the two ends being complementary so that two bricks can have their convex



and concave ends interfitted and may be adjusted angularly relatively to each without leaving openings between them. The ends of the brick follow the curve of an arc of a circle having a radius equal to half the width of the brick. For coupling any two bricks together a coupling tie member B of T shape is provided, the end opposite the cross piece having a downturned lug. The two ends of the brick are grooved to receive this coupling tie, the convex end having a curved groove C which follows the curvature, and at the centre of the concave end a T-shape groove D is formed, the groove being cut away to a depth which is at least as great as the thickness of the tie, so that the latter will lie flush or below the top surface of the brick. The convex groove C receives the tie lug, and so that the tie shall lie flush with or below the top surfaces of two adjacent bricks, the convex end of each brick is cut away around the tie-receiving groove to form a recess or step below the upper face of the brick at a depth at least as great as the thickness of the tie. The groove extends below the surface of the step so that the tie may lie on the step with the lug projecting into and engaging the groove.—*July 11th*, 1939.

509,331. February 4th, 1938.—ELECTRIC FUSES, The British Thomson-Houston Company, Ltd., of Crown House, Aldwych, London, W.C.2.

An object of this invention is to provide a fuse in a single cartridge which will provide reliable protection from both overload and short circuits and which is simple in form and construction. The blow-out fuse element (Fig. 1) for interrupting overload currents is indicated at A and a high-tension, high-power fuse element for disconnecting heavy short circuits at B. The latter has a fusible conductor situated in a sand filling, and is spirally wound on a fire-resisting insulating support. The overload current fuse A is situated in the extended insulating tube C of the short-circuit fuse B and is closed by a cap D which flies off directly sufficient pressure is developed in the tube C. Instead of the cap D a silencer may be provided, which can also



be used as an exhaust cooler. It may easily happen that the blowing-out phenomena will be slight on account of the small currents in the case of overload and on account of very brief duration of current in the case of a short circuit. The overload fuse part A in Fig. 2 comprises a body portion of insulating material having a tortuous channel E formed by alternating upwardly and downwardly extending partitions. The fusible conductor F is arranged in the channel E and the spaces between the upper ends of the downwardly extending partitions are closed by stoppers G, which are arranged to be blown out by excess internal pressure in the event of a heavy current interruption, but remain in their places in the event of interruption by a light overload. Instead of arranging the channel in one

plane it could be formed around a cylindrical body in various ways.—*July 14th*, 1939.

TRANSMISSION OF POWER

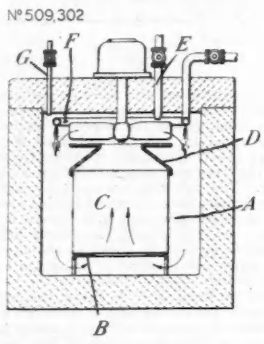
509,722. February 11th, 1938.—Electric Cable Installations, Felten and Guilleaume Carlswerk Aktiengesellschaft, of Köln-Mülheim, Germany.

In recent years a cable for very high voltages has been introduced in which the cable is kept in a steel tube under outer pressure in order to avoid inner hollow spaces. It has been found that the usual lead sheathing can be replaced by a sheathing of synthetic material. The object of the invention is to apply this idea to cables for heavy currents, *e.g.*, paper-insulated cables, for the transmission of heavy currents at comparatively low voltages, up to a few thousand volts. The invention consists in an electric cable in which an insulated cable surrounded by a protectjve sheathing of synthetic material such as polyvinyl chloride is drawn into a tube consisting of steel pipes welded together without being subjected therein to pressure, as is the case with cables carrying currents of very high voltages.—*July 20th*, 1939.

FURNACES

509,302. January 8th, 1938.—Case-hardening of Ferrous Metals, Wild-Barfield Electric Furnaces, Ltd., Eric Philip Barfield, and John Edward Oram, all of Elecfurn Works, North Road, Holloway, London, N.7.

Ferrous metals have been case-hardened by heating the metal in a furnace of which the atmosphere comprises a mixture of carbon-rich gas which may be mixed with ammonia. An object of the invention is to provide an improved method and improved means for adequately mixing carbon-rich gas and ammonia vapour in a furnace in which ferrous metals are to be case-hardened and for distributing and circulating this mixture throughout and around the metal to be treated. The accompanying drawing is a diagrammatic view of one form of furnace. The furnace chamber A has a platform B on which the charge C can be placed. A fan motor is mounted on the furnace and its shaft projects through the roof. The fan has blades which are inside the furnace chamber. The fan circulates the furnace atmosphere down the outside of the charge and thence up through the charge as shown by the arrows, the atmosphere being directed into this path by a baffle D forming a throat above the charge. A pipe E passes through the furnace roof in such a position that oil can be dripped through this pipe on to the blades of the fan. A ring of nozzles, for example, a perforated ring F, surrounds the fan blades coaxial with the fan shaft and ammonia vapour can be led to these nozzles through a pipe passing through the roof of the furnace. A curtain of ammonia-

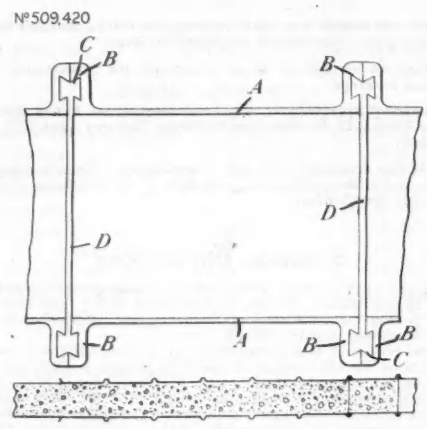


vapour is thus provided around the fan blades which throw the vaporised oil through this curtain and intimately mix the hydrocarbon vapour and the ammonia vapour. A small vent G controlled by a cock is provided to permit purging of the furnace and to allow some of the gaseous atmosphere to escape from the chamber during treatment of the charge, the vent being reduced by means of the cock after purging. This escape of gas is made up by fresh gas generated by the vaporisation of hydrocarbon oil by the hot blades of the fan and the mixing of this vapour with ammonia vapour. The furnace is charged with the material to be treated and is purged with the mixed carbonising and nitriding atmosphere whilst the fan is running, the vent being open to allow the air to escape. Running the fan during purging ensures the speedy distribution of the gas to contact with each part of the charge. After purging, the vent is reduced and the charge heated, the fan being run during this heating in order to ensure uniform quality of gas. The point where the oil and ammonia (the carbonising and nitriding agents) are admitted is so chosen that it is only after thorough admixture together and after passing through a heating zone with the gases already circulating in the furnace that the gases come into contact with the charge. In some cases the furnace is pre-purged with an inert gas, this pre-purging taking place without heating and without running the fan. The furnace is then purged by the mixed carbonising and nitriding gases with the fan running as previously described.—*July 10th*, 1939.

BUILDING

509,420. January 14th, 1938.—Sheet Piling, Leslie Spencer Graham Homewood, 74, The Drive, Fulham, London, S.W.6.

Sheet piling in accordance with the invention comprises spaced parallel rows of outer members connected by transverse diaphragm members which engage with the outer members in each row to lock adjacent members of the row together. The piling comprises an outer sheet pile A of channel section, having thick flanges B. The web portion of the channel has a flat outer surface so that smooth surfaces are given to concrete cast between two piles spaced apart. The flanges have undercut grooves C, the cross section of which may be of any suitable shape. In forming a duplex sheet piling, two outer sheet piles are spaced apart by transverse diaphragms D, which have undercut projecting portions fitting the grooves in the flanges of the outer members. These undercut portions project from each side of the diaphragm so that the flanges of two adjacent outer piles may be engaged together, the outer surfaces of the piles being then aligned. The application of these piling members to the construction of a continuous reinforced concrete wall is illustrated. A number of pile boxes are driven, each box comprising two outer sheet piles spaced apart by a diaphragm and each box being keyed to the adjacent box by the projections on the diaphragms. Each pile box may be driven by driving a mandril around which the interlocked piling members are arranged to form the box, the piling members being taken down with the mandril. When the piling members have been driven to the required depth the mandril is withdrawn. Reinforcement is then placed in the boxes and concrete is poured in. The concreting is carried out consecutively, and as it is done, the diaphragms are withdrawn after the concrete has been placed, thus allowing the fresh concrete to form a continuous wall without joints. The side piles are left in position until the concrete has taken its initial set and are then withdrawn. Whilst one part of the wall is being concreted further boxes are added to extend the wall, so that the construction of the wall is substantially continuous. The piling can also be used



as an ordinary sheet piling cofferdam, and in order to make the joint watertight, the spaces in between the parallel walls can be filled with suitable water-resisting substances.—*July 14th*, 1939.

METALLURGY

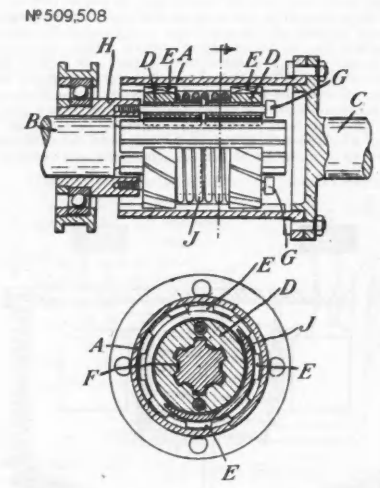
509,442. March 18th, 1938.—Improvements in the Manufacture of Steel, H. A. Brassert and Co., Ltd., Granite House, Cannon Street, London, E.C.4 (a communication from abroad by *Tom Peach Colclough, at H. A. Brassert and Co., of* 69A, *Wilhelmstrasse, Berlin*).

The object of this invention is to permit the casting of "rimmed" steel into ingots with a regulated amount of "rimming" and greater freedom from the well-known defects of blow-holes under the skin and greater freedom from inclusions and internal cavities. There is provided a method of manufacturing steel comprising the steps of adding both aluminium and fluorides in small quantities to the steel while it is being cast in the moulds. Calcium fluoride and/or sodium fluoride may, for example, be used. The addition of aluminium regulates the "rimming" by reducing the amount of iron oxide which is present in the steel. It also results in the formation of inclusions of alumina and manganese oxide, which are detrimental to the physical and chemical properties of the steel. The action of fluorides is that of a cleansing agent to remove suspended impurities, and also, to some extent, to degasify the metal. The effect of adding both aluminium and fluoride is effectively to cleanse the steel from the alumina and manganese oxide inclusions, fluxing them and allowing them to rise to the surface of the steel.—*July 17th*, 1939.

MISCELLANEOUS

509,508. January 22nd, 1938.—Shaft Couplings, Albert George Elliott, Holmwood, Quarndon, Derby.

The shaft couplings described provide a drive between two shafts and permit of angular adjustment between the driving and driven shafts whilst in motion. The invention is applicable to the timing control of the magneto for an internal-combustion engine. A sleeve A, which surrounds the driving shaft B, is bolted to a flange on the shaft C. Splines are formed on the shaft B and on the inner surface of the sleeve, one set of splines being helical and the other of different pitch, and in this particular example the splines on the inner surface of the sleeve are helical and the splines on the shaft are parallel with the common axis of the shafts. The driving engagement between the sleeve and the shaft B is effected by a pair of blocks or collars D in the annular space between the sleeve and the shaft, and these collars are formed with extending projections or keys E to engage the splines on the inside of the sleeve and with similar projections F to engage the splines on the shaft. Two spindles G extend freely through the collars and are carried



by a sleeve H which is mounted in bearings so as to be movable along the shaft under any suitable control. The two collars are pressed apart longitudinally by a spring J situated between them, and heads on the ends of the spindles constitute abutments by which pressure can be applied to the adjacent collar whilst the end of the sleeve G provides a shoulder by which pressure can be applied to the other collar. A small clearance is provided between the collars so that they can be moved relatively to one another on the spindles, and, when they are in their working position, engaging the two sets of splines, there is also a clearance between each collar and its adjacent co-operating shoulder. The fact that the two blocks or collars are spring-pressed apart whilst engaging two sets of relatively inclined splines ensures that any slack is taken up and that they are self-locking, because they wedge themselves in the splines; when it is desired to effect angular adjustment between the driving and the driven shafts, the spindle-carrying sleeve is moved in one or other direction and during this movement the clearance between the operating shoulder and the block is first taken up, then that block is moved towards the other block, compressing the spring between them, and this small movement suffices to release the blocks from their wedging effect in the splines; continued movement of the operating sleeve then moves the two blocks together lengthwise of the spline and effects angular adjustment of the shaft and its surrounding sleeve. When the desired angular adjustment has been effected, the motion of the operating sleeve is stopped, and the compression spring forces the two blocks apart, thereby locking them again by the wedging effect in the splines. The construction provides a coupling in which there is no slack at any time, and any slack which develops is automatically taken up, and which is self-locking in all positions; further, it is self-releasing by the action of adjusting the parts in the desired manner.—*July 18th*, 1939.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of its insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

Association of Special Libraries and Information Bureaux
Friday to Monday, Sept. 15th to 18th.—University College, Nottingham. Sixteenth Annual Conference.

British Association for the Advancement of Science
Wednesday to Wednesday, August 30th to Sept 6th.—Annual meeting at Dundee.

Engineering and Marine Exhibition
Thursday to Saturday, Sept. 14th to 30th.—Olympia, London, W.6.

Institute of British Foundrymen
Saturday, August 26th.—Lancashire Branch. Visit to works of Lancashire Foundry Coke Company, Accrington. 1.30 p.m.

Institute of Metals
Tuesday to Friday, Sept. 5th to 8th.—Autumn meeting in Glasgow.

Institution of Electrical Engineers
Friday to Sunday, Sept. 15th to 17th.—Transmission Section. Summer visit to Yorkshire.

Institution of Mechanical Engineers
Saturday to Sunday, August 26th to October 1st.—American Summer meeting.

Iron and Steel Institute
Tuesday to Friday, Sept. 12th to 15th.—Autumn meeting in Cardiff.

North of England Institute of Mining and Mechanical Engineers
Saturday, August 26th.—Neville Hall, Newcastle-upon-Tyne. Annual general meeting. 2.30 p.m.

Railway Club
Thursday, Sept. 7th.—Royal Scottish Corporation Hall, Fetter Lane, E.C.4. "Railway Rambles in Galloway," H. A. Vallance. 7.30 p.m.

PERSONAL AND BUSINESS ANNOUNCEMENTS

E. K. Cole, Ltd., announce the appointment of Mr. S. W. Fuller as sales manager for Ekco lamps.

Mr. J. B. Talbot-Crosbie and Mr. W. Kilpatrick, directors of Duncan Stewart and Co., Ltd., have joined the board of Davy and United Engineering Company, Ltd., and Mr. Kilpatrick, as director and commercial manager, has taken up his position at the company's head office in Sheffield.

B.E.N. Patents, Ltd., High Wycombe, Bucks, manufacturers of air compressors, paint-spraying plant and garage equipment, have opened a new service depôt and showroom at 92, Tottenham Court Road, London, W.1. The new branch is under the management of Mr. A. Kingwell.

CONTRACTS AND ORDERS

The Editor is always happy to print short announcements of contracts and orders in this column provided they are sent to him in time to have news value and that they are likely to interest readers.

Head, Wrightson and Co., Ltd., Thornaby-on-Tees, have received an order for a special type of lift bridge for the Irish Free State. The design upon which the contract is based follows some years of research by the company's technical staff. The first bridge of the kind to be manufactured by Head, Wrightson was a small experimental bridge erected in South America some years ago.

Patent Retorts, Ltd., 5, Victoria Street, London, S.W.1, has recently received from the South African Torbanite Mining and Refining Company, Ltd., an order for the erection in South Africa of a battery of four rotary Davidson retorts, with rated throughput of about 120 tons per day. These retorts are similar to those which have been in continuous operation in Estonia during the past eight years.

The English Electric Company, Ltd., has received a contract for a number of single-deck bus bodies from the Lancashire United Transport and Power Company, Ltd. In addition, repeat orders have been received from Warrington Corporation for double-deck all-metal bus bodies, from Preston Corporation for double-deck composite bus bodies, and from the Potteries Motor Traction Company for single-deck composite bus bodies. These contracts will be carried out at the English Electric Company's Dick Kerr Works, Preston.

The British Thomson-Houston Company, Ltd., has recently received from the Great Western Railway Company an order for converting equipment to augment the supply to the electric line between Paddington and Hammersmith. The order comprises five air-cooled steel tank rectifiers of 1500 kW capacity each, with tuned smoothing circuits, associated A.C. and D.C. switchgear and twelve track feeder equipments. The rectifiers will be installed in two existing substations, where they will replace some very old motor converters.

Crossley Brothers, Ltd., Openshaw, Manchester, have recently received orders for one six-cylinder vertical Diesel engine, 510 B.H.P., for Tanganyika Central Gold Mines; two five-cylinder pressure-charged Diesel engines, totalling 660 B.H.P., for Downs Dairies, Australia; two five-cylinder vertical Diesel engines, totalling 1000 B.H.P., for Kalabagh Head Works, Punjab, and two four-cylinder vertical scavenge pump Diesel engines, totalling 220 B.H.P., direct coupled to generators, for lighting purposes at Manchester Ship Canal, Eastham Locks.